GENERAL AND PROFESSIONAL BIOLOGY

EDWARD J. MENGE

GENERAL AND PROFESSIONAL BIOLOGY

with Special Reference to Man

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THIRD EDITION, REVISED

VOLUME I
GENERAL BIOLOGY

THE BRUCE PUBLISHING COMPANY
MILWAUKEE, WISCONSIN
NEW YORK - CHICAGO

Printed in the United States
of America

To My Students

whose loyalty and appreciation have been my inspiration throughout the years this book has been in preparation.

PREFACE TO THE THIRD EDITION

With the ninety-third adoption of this volume as a classroom text, the need for another new edition arises. A number of changes have been made, not only in the interest of later scientific findings, but also where the text or illustration lent itself to some misinterpretation. Several illustrations have been redrawn so as to make them more usable by the student.

Again, the author and the publisher welcome any suggestions or criticisms which will make further editions of this book of still greater service.

EDWARD J. MENGE.

July 1, 1928.

PREFACE TO THE SECOND EDITION

Although the first edition of this work came from the press too late for use in the first semester, the extraordinary reception accorded it, especially by medical educators and medical journals, necessitated immediate preparations for a second edition.

The work has been gone over carefully, and various changes have been made where it has been found that the student would profit by such changes and the entire work has been reset. It is now issued in two volumes so as to accommodate those schools which, presenting only general biology, require but the first half of the subject matter.

Two objections have been raised by several critics: (1) that the chapters "Why to Study," "How to Study," and "The Coördination of Subjects Studied," have as much place in any textbook on Chemistry or Physics as they have in a work on Biology, and that in reality they have no place in either; and (2) that the apparent lack of organization in the third portion of the work (now the latter half of Volume II) prevented the student from obtaining a clear-cut line of demarcation between Anatomy and Physiology.

Regarding the first objection: There are actually only two real coördinating subjects in the college curriculum—Philosophy and Biology. And, as very few students of the sciences ever take any of the philosophical courses, the only department left, where coördination can be driven home effectively, is Biology.

Further, the author spent practically an entire school year visiting the leading universities in this country and abroad to find how and where to improve the various courses. He found deans and professors alike agreeing that the most important thing that could be given a student during the first years of his college work was the manner and the means of learning **how to study, why to study, and how to coördinate the subjects studied.**

He then took the laboratory courses as given in our American schools of medicine so as to obtain first-hand information as to what professional students actually need. This work is the result.

Regarding the second objection: There are no such artificial lines of demarcation in the living organism as are used in the laboratory. Anatomy and Physiology are most intimately interwoven in life. Therefore, in order that the student obtain a realization of the artificial laboratory grouping, as well as the actual conditions in the living organism, the first half of the book keeps Anatomy and Physiology separate and distinct, except where the two can be shown to be intimately related, while the third portion of the work interweaves the two branches. This **apparent** lack of organization and separation of the two branches of science was, therefore, of deliberate intent.

EDWARD J. MENGE.

January 1, 1924.

PREFACE

Teachers of the Biological Sciences have often observed that:

(1) The majority of American college students are the children of parents who have not had a college training and, therefore, have no proper conception of what a college course means, nor an understanding of the reasons that lead educators to place certain studies in the curriculum instead of others.

(2) The work done by the average student up to his entry into college has neither taught him **how** to study, nor how to coördinate the work of the various courses he has had.

(3) The technical words he has met with have not been analyzed, so that he has no conception of their derivation, and, consequently, of their true meaning. He has largely memorized whatever was learned with little understanding of meanings.

(4) The professional world (especially of medicine and dentistry) is in general accord with the idea that "General Biology" or "General Zoölogy" should be followed by "Introductory Embryology" and "Comparative Anatomy."

(5) Most texts on the biological sciences either try to make the subject matter entirely too easy, and thus forget to mention the many points of prime interest to professional students, or they try to cover the entire range of animal biology, thus burdening both book and student with matter that will be forgotten as soon as examinations are passed.

(6) The student is, therefore, confronted with several alternatives: Either he takes the "easy" course and feels that because he was told so little, there is but little to be told. Or if the more detailed course has been taken, he finds that it has helped him but little, if any, in his chosen field, and he is rightfully disappointed.

(7) The terminology in Botany, Zoölogy, and Medicine is by no means identical, and much must be relearned by professional students.

(8) A textbook usually confines itself to "Type Forms" or to "General Principles." In either case, the student suffers for want of the half that is left untold.

(9) Results of scientific work are often given, such as the life-cycle of the Malarial Parasite, without showing in detail the type of work necessary to bring about those results, thus preventing the student from gaining one of the most valuable lessons of his scientific course.

(10) Medical and Dental educators, as well as students themselves, are constantly complaining of the insufficient stress placed on Histology and Neurology in the preliminary courses, as it is in these fields that so many students later find their greatest difficulties.

(11) Medical educators insist that in a few years all medical schools must add a course in Medical Zoölogy. The students who are

now being prepared for these courses must obtain an adequate number of examples of animal parasites in their premedical studies, or they will not be able to profit fully when such later course is taken.

(12) The student now purchases three, and often four, texts for his biological work, none of which is a true continuation of its predecessor.

(13) When studying a given biological problem, constant reference must be made to facts and findings of various kinds, for the purpose of checking up and coördinating the work one is doing. If a student must seek through many volumes for such references, he is all too likely not to look for any at all; whereas, if he has but to turn a few pages, he will almost invariably search out many.

Being confronted with points such as these, and wishing to obtain the professional student's point of view as well as an understanding of his difficulties, the author has taken the regular laboratory courses offered in American schools of medicine, and has built this book on what experience has taught him to hold most valuable.

Therefore, he begins (1) by showing the student **why** to study, and (2) **how** to study and **how** to **coördinate** the various courses of the curriculum. (3) The glossary is made quite complete by giving both derivations and pronunciations of all technical words used in the text, and the student is then asked to write them out in the parentheses left blank for that purpose. (4) "General Biology" is followed by "Introductory Embryology" of the Chick and Frog, with a general statement regarding Mammalian Forms, thus presenting to the student the beginnings of a Comparative Study. This, then, is followed by "Comparative Anatomy" where constant comparisons are not only made, but where back references are brought into play to force a repetition, so essential to a full understanding of all scientific work.

(5) One subject (the Frog) is treated exhaustively, so that the student will not be burdened with too good an opinion of his own knowledge of even so humble a thing as the frog, while principles are always presented **after** the facts have been shown upon which those principles rest.

(6) The entire work is concentrated and by no means "easy." The goal of the student is kept in mind.

(7) The terminology which the professional student will use later is always borne in mind and stressed.

(8) "Type Forms" are studied, but only in so far as these are necessary to a full and complete understanding of both the anatomy and physiology of the animal, and to furnish the facts on which to build interpretations and principles.

(9) In such work as that on the Malarial Parasite, the result of scientific work is first shown so as to cause the student to wonder how such a mass of intricate detail could ever have been discovered. Then a detailed account of the painstaking and intelligent effort necessary to make such findings valuable is given.

(10) Histology and Genetics are stressed, because in all biological

work a thorough knowledge of the cell and tissues is a prerequisite for further work, and Neurology, because of its tremendous importance in all biological, psychological, and medical fields.

(11) Examples, wherever possible, have been chosen in so far as they add to, or detract from, human welfare, for, after all, students of Education, Law, Philosophy, Psychology, Sociology, Theology, Economics, Engineering, Medicine, and Dentistry are, and must be, most interested in Man.

(12) All that is needed for two complete years of biological work is contained within this work. Each part logically follows the part preceding, and thus not only saves the student considerable time and expense, but also serves him as a sort of continual reference work in his future professional years of study. Both the Bee and the Grasshopper have been included so that teachers may use their preferred form.

(13) Then, too, the student who has his entire course of study before him in a single work, often, of his own volition, reads much more than he normally would were the subject matter scattered through several texts, for it is an easy matter to refer to another closely related subject if the reference can be found by merely turning a few pages.

The book is so written that it can be used as a text for General Biology, General Zoölogy (by merely omitting Chapters XV and XVI), for Introductory Embryology, and for Comparative Anatomy.

Where only one year is given to biological work, as in many Dental Schools, it is suggested that the first semester be given to "General Biology" or "General Zoölogy" made up of selected chapters from the first half of the text, while the second semester be confined to the higher forms such as Dogfish, Turtle, and Cat or Rabbit, as found in "Comparative Anatomy."

The "Laboratory Manual for Biology and Embryology," by Professor John Giesen, should be used with "General Biology" and "Introductory Embryology."

Dr. L. H. Hyman's "A Laboratory Manual for Comparative Vertebrate Anatomy" (University of Chicago Press) is being used for the comparative work in Anatomy.

Long bibliographies have not been given in this book, as these are seldom consulted by a student during the first two years of his college career. However, as all of the books mentioned on pages 12 and 13 should be in every college library, those who wish such bibliographies can find the best in Kellicott's "Chordate Development," Patten's "The Early Embryology of the Chick," and Kingsley's "Comparative Anatomy of Vertebrates."

It is much more important for the student to know **HOW to Compile a Bibliography** than to look over one already made. Therefore, in the author's classes a different subject is assigned each student to look up, for the purpose of compiling a bibliography of everything written on that subject for the past forty years. Such subject may be taken from any index of the Journal of the American Medical Association.

Forty years are chosen because it is about that many years ago that some of the larger indices were compiled, and it is essential that the student be forced to go through all the indices year by year. If the indices are not found in the smaller towns and cities, the bibliography can be made during one of the vacations when the student passes through some of the larger cities where there is a medical or scientific library.

The more important indices published in the English Language are:

The Zoological Record (published yearly by the Zoological Society of London. Each volume gives a complete list of the works and publications relating to zoology in all its branches that have appeared during the preceding year. The first volume was for the year 1864).

The Index Medicus (Found in any Medical Library).

Index Catalogue of the Surgeon General's Office.

International Catalogue of Scientific Literature, "Zoology," "Botany," "General Biology." (Pub. by Harrison & Sons, 45 St. Martin's Lane, London.)

For popular articles:

The Reader's Guide to Periodical Literature.

The International Index to Periodicals. (Before Jan., 1921, The Reader's Guide to Periodical Literature Supplement.)

The books which have been of greatest service to the author are:

On General Biology

Parker and Haswell, "Text-book of Zoology."
L. A. Borradaile, "A Manual of Elementary Zoology."
Shipley and MacBride, "Zoology."
R. W. Hegner, "College Zoology."
J. G. Needham, "General Biology."
Linville and Kelly, "A Text-book in General Zoology."
O. H. Latter, "The Natural History of Some Common Animals."
Schull, Larue, and Ruthven, "Principles of Animal Biology."
A. M. Marshall, "The Frog."
S. J. Holmes, "The Biology of the Frog."
H. S. Pratt, "A Manual of the Common Invertebrate Animals."
Ward and Whipple, "Fresh-Water Biology."
Sanderson and Jackson, "Elementary Entomology."
Leland O. Howard, "The Insect Book."
J. H. and Anna B. Comstock, "A Manual of the Study of Insects."
Frank E. Lutz, "Fieldbook of Insects."
J. W. Folsom, "Entomology with special reference to its Biological and Economic Aspects."
Riley and Johannsen, "Handbook of Medical Entomology."
W. T. Calman, "The Life of Crustacea."
R. W. Hegner, "The Germ-Cell Cycle in Animals."
W. E. Agar, "Cytology, with Special Reference to the Metazoan Nucleus."
L. Doncaster, "An Introduction to the Study of Cytology."
L. W. Sharp, "Introduction to Cytology."
C. Hill, "A Manual of Normal Histology and Organography."
Krause-Schmahl, "A Course in Normal Histology."
W. E. Castle, "Genetics and Eugenics."
E. G. Conklin, "Heredity and Environment in the Development of Man."
C. B. Davenport, "Heredity in Relation to Eugenics."
East and Jones, "Inbreeding and Outbreeding."
H. E. Walter, "Genetics."
T. H. Morgan, "A Critique of the Theory of Evolution."
S. J. Holmes, "The Evolution of Animal Intelligence."
M. F. Washburn, "The Animal Mind."
H. S. Jennings, "Behavior of the Lower Organisms."

Eric Wasmann, "Instinct and Intelligence in the Animal Kingdom."
James Johnstone, "The Philosophy of Biology."
A. D. Darbishire, "An Introduction to a Biology and Other Papers."
Vernon L. Kellogg, "Darwinism Today."
Wm. A. Locy, "Biology and Its Makers."
H. F. Osborn, "From the Greeks to Darwin."
C. E. and E. A. Bessey, "Essentials of College Botany."
Bergen and Davis, "Principles of Botany."
C. S. Gager, "Fundamentals of Botany."
Wm. C. Stevens, "Plant Anatomy."
Strasburgher's "Textbook of Botany."
D. H. Campbell, "A University Textbook of Botany."
Coulter, Barnes, and Cowles, "Textbook of Botany."
I. F. and W. D. Henderson, "A Dictionary of Scientific Terms."

On Embryology

F. R. Lillie, "The Development of the Chick."
W. E. Kellicott, "Chordate Development."
B. M. Patten, "The Early Embryology of the Chick."
Prentiss and Arey, "Textbook of Embryology."

On Comparative Anatomy

G. C. Bourne, "An Introduction to the Study of Comparative Anatomy."
J. S. Kingsley, "Comparative Anatomy of Vertebrates."
L. Vialleton, "Elements de Morphologie des Vertebres."
Schimkewitch, "Lehrbuch d. vergl. Anatomie d. Wirbelthiere."
H. H. Newman, "Vertebrate Zoology."
H. W. Wilder, "History of the Human Body."
Parker and Haswell, "A Textbook of Zoology."
L. H. Hyman, "A Laboratory Manual for Comparative Vertebrate Anatomy."
H. S. Pratt, "A Course in Vertebrate Zoology."
Reighard and Jennings, "Anatomy of the Cat."
Davison and Stromsten, "Mammalian Anatomy, with special reference to the Cat."
O. C. Bradley, "A Guide to the Dissection of the Dog."
Hans Gadow, "Amphibia and Reptiles."
B. F. Kaupp, "The Anatomy of the Domestic Fowl."
C. J. Herrick, "An Introduction to Neurology."
Emil Villiger, "Brain and Spinal Cord."
S. W. Ransom, "The Anatomy of the Nervous System."

The author wishes at this point to thank all those who have assisted him in any way. Thanks are due to Professors Wm. A. Locy, F. R. Lillie, H. S. Pratt, C. W. Ballard, Dr. L. H. Hyman, and Mr. W. C. Clute, and their publishers, as well as to Professor J. H. McGregor, for permission to use various cuts from their published works. Credit is given in the legend of each cut. Thanks are due Professors J. A. Bick of Loyola University, Edward Menager of the University of Santa Clara, Wm. Atwood of the Milwaukee Normal School, and Dr. Peter P. Finney of the University of Dallas for reading much of the manuscript and offering valuable suggestions.

Thanks are due for detailed reading and technical criticism of the manuscript to the following: Professor Richard A. Muttkowski, of the University of Idaho, for going over the greater portion of the entire manuscript; Dr. L. H. Hyman, of the University of Chicago, for going over the portion devoted to "Comparative Anatomy"; Professor Eben J. Carey, of Marquette University, for going over the entire portion devoted to "Embryology"; Professors W. N. Steil of the University of Wisconsin, J. G. Brown of the University of Arizona and the Carnegie Desert Botanical Laboratory, and Sister Mary Ellen, of Santa Clara College, for going over the portions on Botany; Professors Joseph Jastrow, of the University of Wisconsin, and George A. Deglman, of Marquette University, for reading the portions devoted to Psychology; Professor John B. Kremer, of Marquette University, for reading the portions devoted to Geology and Paleontology; Professor Edward Miloslavich, late of the University of Vienna, for reading those portions on Immunity and Pathology; Professor Alfred V. Boursy, for reading the glossary, and Professor Robert Bauer, for reading the chapter on Coördination.

Thanks are due Mr. Leo Massopust, Mr. Lane Newberry, and Mr. Frank Leibly for the many and painstaking drawings they have made, and to Mr. Arthur Vollert, Mr. Frank Krause, Mr. Gervase Flaherty, Mr. Norman O'Neill, Mr. Frank Freiburger, Mr. Robert Schodron, Miss Phyllis Schnader, Miss Irma Gall, and Miss Nathalie Hart for the many hours of assistance rendered in seeing the book through the laborious processes of printing.

The author's appreciation must be extended to his fellow charter members of the Baconian Society, Professors Walter Abel, Alfred V. Boursy, John Giesen, and Edward Miloslavich, for assistance and criticism rendered in discussing innumerable points at their meetings.

And lastly, the author would be remiss in his duty did he not express his special thanks and appreciation to his co-worker of many years, Professor John Giesen, whose loyalty and willingness to assist in every way have made many additional hours of work possible on this book.

EDWARD J. MENGE.

Marquette University,
Milwaukee, Wisconsin,
June 25, 1922.

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PART I

General Biology

CHAPTER I

WHY STUDY

TWO hundred and sixteen (216) **separate and distinct combinations can be formed by three dice of different design,** as shown in the drawing (Fig. 1). On the principle of chance, if these three dice are thrown an infinite number of times, each one of the 216 combinations will appear just as often as every other one.

This is true only if the dice are not weighted. Combinations formed by three dice have been chosen because there are usually at least three alternatives in any case where a man's judgment or opinion is required or asked for. Further, an analogy can be found in the complete human individual where the

Physical,
Mental, and
Moral

must ever be considered; while on the strictly scientific basis, everything that a man is, or can be, depends upon the three factors:

Inheritance,
Environment, and
Training.

Or, again, no opinion worth anything can be formed without the following three factors being taken into consideration:

Obtaining the facts,
Reasoning thereon,
Forming a judgment or conclusion.

Each dice possessing six sides may be compared to the many facts, conditions, or possibilities that go to make up any one of the three great factors appearing in the tables above.

It is self-evident from this that in any given case, where there are three factors with six possibilities contingent upon each, **unless life's dice are weighted by knowledge, a man's opinion stands only one chance in 216 of being correct.**

The almost ideal laboratory evidence that substantiates these statements is found in the fact that out of three thousand cases at one of our leading hospitals, the diagnosticians were correct only 53.5 per cent of the time.[1] **If, at our most important institutions, the ablest and best trained men, working with the finest equipment obtainable, are correct only approximately one-half the time,** it means that on the principle of chance, when anyone passes an opinion or comes **to a conclusion without all obtainable knowledge, he cannot approach correctness even this often.**

[1] "Diagnostic Pitfalls Identified During a Study of Three Thousand Autopsies," by Richard C. Cabot, M.D. *Journal of the American Medical Association,* pp. 2295-2298, Dec. 28, 1912.

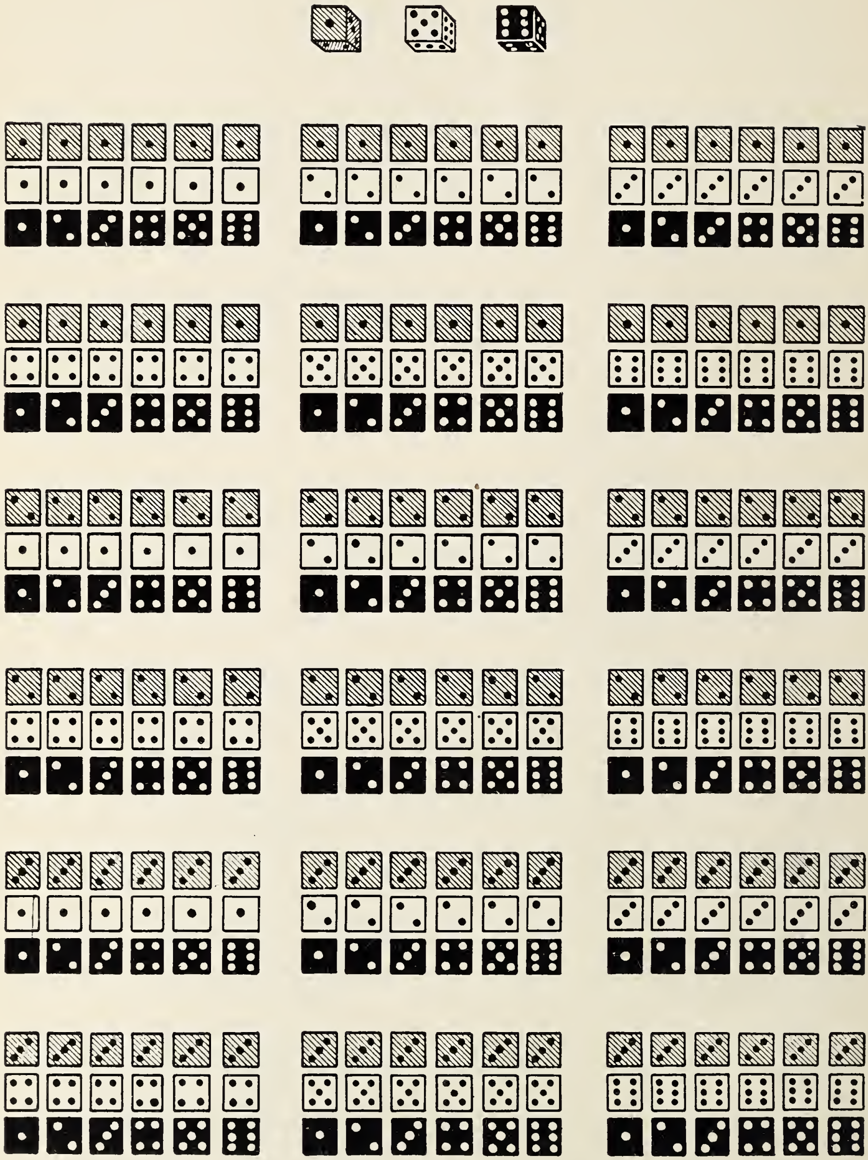

Fig. 1.

Probability of Error Chart (showing there are 216 different combinations possible with three dice of different design).

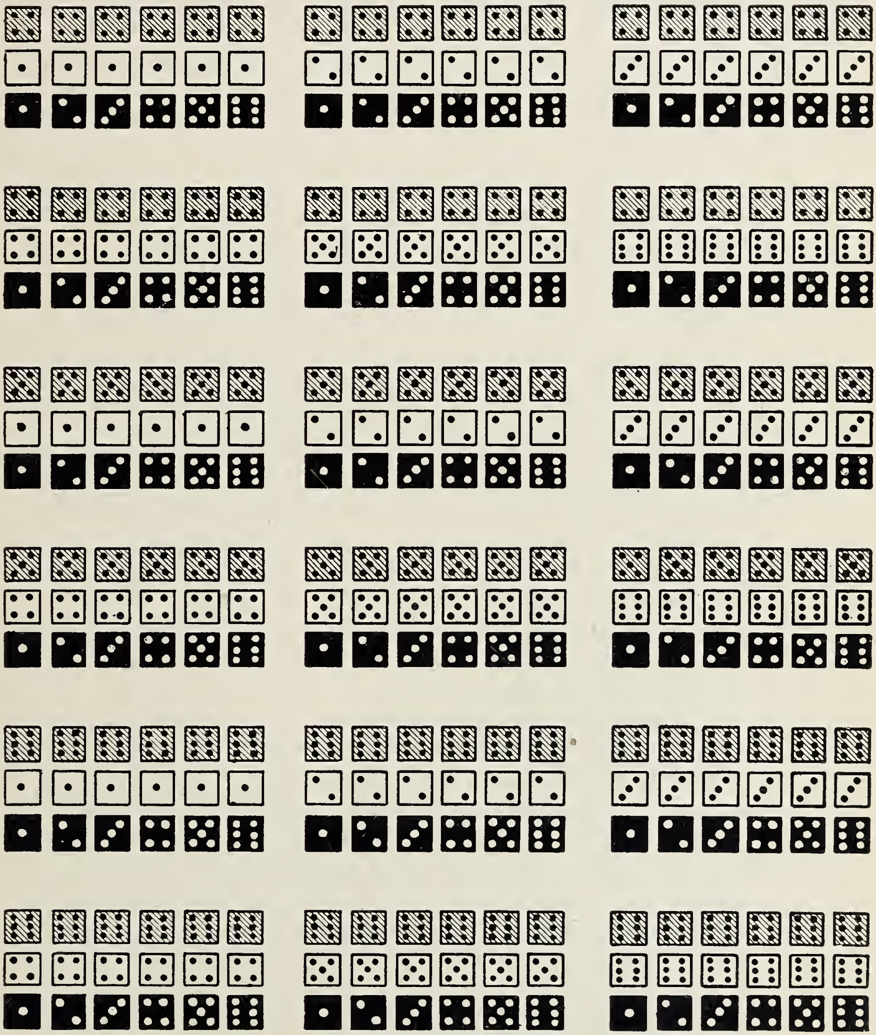

Fig. 1.

The evidence forces the conclusion that, under present conditions, if we should know all that it is possible for a human being to know, we could be right only about one-half the time. As knowledge is the only way in which we can be right even as frequently as this, it follows that when an opinion is called forth without any knowledge, a man forms approximately 215 erroneous conclusions to every one that is correct. The scriptural command becomes intelligible: "Get ye therefore knowledge."

It has been said that the evidence from diagnostic sources is almost ideal to illustrate the point here made. Everything we do that requires an opinion is pure diagnosis. In other words, every time one passes a judgment upon the facts presented, it is a diagnosis of some kind, and any error in our diagnosis means that no intelligent suggestion can come forth as to a remedy, except on the basis of one correct one to 215 erroneous ones. The diagnosis must be correct or the remedy is absurd with the only possible exception of a guess accidentally correct.

No intelligent person wishes to have his government run, his estate adjusted, his house built, or his farm managed upon pure guess work in which the chances are that two hundred and fifteen times more wrong things will be done than right ones. And this is not only the case in medicine, dentistry, and the professions at large, but in the every-day business world as well. Dun and Bradstreet, who keep a record of every individual entering, as well as every one failing in business, tell us that 95 out of every 100 men who enter a commercial line for themselves fail at some time in their lives. This is due, not only to an ignorance of the particular line of work they may enter, but also to ignorance of business principles and methods at large.

To many persons it seems that the purely practically-trained individual is better equipped than he whose training has been theoretical, and individuals usually mentioned as examples to illustrate this point are among the ablest practically-trained men to be found, who are then compared with some of the poorest theoretically-trained. Because a boy is sent to college does not mean anything except, that, if he has a capacity for the work he takes up, he will be able to get the practical side of his study, while in addition he will learn why he does what he does, when he does it. Any man with great ability along a given line will naturally know more, and be able to work better along that line than any man without such capacity who has merely taken some theoretical course. But, if we take two men of equal intelligence and capacity, who take up, let us say, the plumber's trade, he who has mastered both the practical and the theoretical side of his work will always be superior to him who has become interested in only one or the other. It must be remembered that

(1) Capacity,
(2) Opportunity, and
(3) Application

are essential to make a master of anyone in anything.

It takes considerable time to show the fruits of any study, and men are impatient for results.

Someone has truly said that the value of education consists in **knowing a man when you meet one**; which means, of course, that anyone knowing his subject-matter in a given field will be able to know whether one **claiming** to be an expert in that field speaks truthfully or not. It means that we must **know** about a matter ourselves or we cannot intelligently choose worthy leaders. It means, we must be able to distinguish gold from dross, real ability from advertising, scientific men from those who are simply well known. It means that we must be able to distinguish between the **real expert** and **him who calls himself one**, remembering that experts do not disagree very much, but those who call themselves experts do.

Whether we like it or not, we must acknowledge that every man who has lived and exercised any kind of leadership, good or bad, has left his impress upon our generation. All those who have gone on before us, together with those living now, as well as those who are to come after us, really form a great intellectual democracy, from which all but the present generation are removed only in person. The past is with us in an overwhelming mass. The unborn are those for whom we now labor. All our customs, our traditions, our ideas of conventional correctness and wrongness, and our laws were given us by men long since passed away. In other words, we are actually ruled by dead men.

The men who have long since passed away have given us their ideas and their thoughts; but, to us those ideas and thoughts, those laws and traditions **must be interpreted**, and our interpreters of these things are our **courts**. Mr. Taft has said, "I care not who makes the laws, if I can but interpret them." It is always meanings, interpretations, which are of most value. Now, we know that **our judges** (our legal interpreters), are practically **all college men**, which means that, in the final analysis, **everyone of us is controlled by what our institutions of higher learning teach.**

It, therefore, behooves each of us to obtain the requisite knowledge before forming an opinion as to whom we shall follow as leaders in every walk of life, whether this be in politics or in war, in civil or religious life, in law or in medicine, in farming or commercial pursuits, or we shall be wrong in nearly everything we do.

Not possessed of knowledge, a man confuses sincerity with truth, forgetting that the most insane of men are intensely sincere, and that anyone following sincere but insane theories of life must quite naturally reap destruction; forgetting that to obtain the truth in anything, **all the facts must be known** and a **valid interpretation placed upon the facts,** and this can only be done by considering man in his entirety—in his physical, mental, and ethical aspects.

One must, therefore, weight life's dice with knowledge if correctness is to be formed in any walk of life.

Nearly every parent desirous of his child's welfare, wishes he could leave the child the benefit of his own experience, so that the child might profit by his parent's mistakes and not make the same blunders. The value of this desire may be appreciated when it is remembered that if experience cannot be handed down, there is absolutely **no progress.** For, each individual, instead of starting where his parents left off and continuing onward, would necessarily have to begin where they began, and, consequently, when life came to a close, the children would be practically where their parents had been at the close of their careers.

Men of the past have, therefore, written their experience in books, and we of to-day can profit not only by the experience of our immediate parents but by that of our forefathers.

The laboratory has gone even a little further than this.

As no one man can work out every detail in the study of a single plant or animal without having to take the work of all those into consideration who have gone before and who have contributed something to the knowledge of the particular plant or animal under discussion, so, men have gathered into a single grouping the important physical experiences which have been found convincing to their minds and have called such grouping a **textbook.**

The study of the subject-matter of a textbook, plus the actual working out of these same convincing experiences (now called **experiments)** in the laboratory, cause the student to **see** the way in which **proof** is obtained for the conclusions men hold.

In fact, laboratory work, plus a study of the text, is the fulfillment of the parent's wish that his child inherit the parent's experience.

From the experiments which give us conclusive evidence of the way some **physical process works,** we draw our **principles.**

Principles are **mental tools** without which no mental progress is possible.

In fact, a principle is a **law of nature, proved by physical experiment, to which no exception has been found.** Physics presents an excellent illustration of the value of principles.[1]

Everyone knows that, if a substance, such as iron, which is heavier than water, is placed in water, it will sink. Yet iron ships do not sink. Why? Because when we speak of anything as "heavier than water" we mean that the same quantity of a given substance is heavier than the same quantity of water.

After Archimedes discovered his **principle,** we knew immediately that, if we could bend iron so that it would occupy more cubic feet of space than that same number of cubic feet of water would weigh, it would be "lighter than water" and would float.

Heavy iron ships could not, however, be of practical use until some one again discovered the principles of steam or electricity, and so they

[1]An old Greek named Archimedes, while taking a bath, discovered that when he immersed his body in a tub filled with water, his body lost considerable weight. Later he was able to prove experimentally that the weight of the water that ran over the top of the tub was exactly the same as the weight his body lost while immersed. It was this discovery which made iron ships possible.

were not used until such principle was found. This shows well the inter-relationship of things that men do, no matter how many years apart the doing may be.

In Biology, which means the Science of Life (Gr. Bios=life+logos=discourse), we are interested in finding **principles,** so that no matter in what position we may be placed in later life, we can always think back, find our principle, and apply it in a thousand and one different ways.

The finding of principles, which is real science, must never be confused with the application of these principles.

The former is what is meant by science, while the latter is merely ordinary labor.

Inventors **apply scientific principles; they are, therefore, not scientists.**

Another point to be remembered is that animals (as well as children before they reach the so-called age of reason) **learn** by doing a thing over and over, until success or failure comes. If success comes, they make such successful endeavor a part of their later life. This is called the **trial-and-error** method of learning.

Educated men and women **do not try out** each and everything, but come to their conclusions by weighing the **evidence for and against a principle**, and if the principle is found to be worthy of consideration, adjust their actions accordingly.

This is well illustrated if one finds a man attempting the invention of a perpetual motion machine. It is a well established **principle of physics** that no more work can be obtained from a machine than is put into it, and even then a little loss must be allowed for on account of friction. All educated men know this law of nature, and consequently do not waste their time on such a fruitless undertaking. But, should any one refuse to accept this principle, there is nothing left but to continue trying and trying, and coming to the conclusion of its uselessness by personal failure.

The **obtaining of principles** is then the **great work of science.** Science itself has had many definitions. Some of the best are:

"Systematized knowledge."

"Classified common sense."

"Checking up and getting rid of one's prepossessions."

"Knowledge gained and verified by exact observation and correct thinking, especially when methodically formulated and arranged in a rational system."

In other words, science means a gathering of **facts, plus** the logical **meanings** or interpretations of **these facts.**

The object or purpose of getting the principles which science thus finds, is **to control** nature and **to prophesy** what will occur when given acts are performed.

As Biology is the science of life, everything that has anything whatever to do with life is really a branch of this science. For example, Biology is not a branch of medicine or dentistry, but medicine and dentistry are branches of biology where men enter into particular details of some division of it.

Biology, therefore, to the medical student, the dental student, the law student, the student of sociology or the student of education, presents a sort of bird's-eye view of the fundamental processes upon which his whole detailed study must be built, so that he can the better and more understandingly read the valuable and meaningful literature of the day and discuss intelligently the very basis on which his every conclusion must rest its truth. In other words, Biology makes it possible for the student the better to be able to prevent men who call themselves experts, but who are not, from deceptively making people believe they are.

CHAPTER II

HOW TO STUDY

SOMEONE has said that to be a **cultured man or woman one must know something about everything; everything about something;** and **never wilfully or maliciously cause suffering to others.**

No better ideal of what a student of Biology should try to attain has ever been written. If all biological **principles** now known are grasped by the student, he can most certainly be said to come as near knowing something about everything as it is possible for him to come.

If he will learn the Frog thoroughly, he can come under the second division of importance; and if he will bear the final of the three injunctions in mind, Biology will be a humanizing and cultural as well as a scientific and laboratory study.

Never read a book, article, or paper, without fountain pen and note-book, or note-paper, beside you.[1]

I. Notes are of no value unless they are usable. There are different types of records for different purposes, but those found most convenient by the author are as follows:

For regular lectures and for general reading—A package of bond paper cut to 4 x 6 inches in size.

Many such sheets can be carried constantly in the pocket if a little heavier paper, or even a piece of cardboard 4 x 13 inches in size, is bent in the mid-line so as to form a covering for the loose cards. A rubber band is placed about the packet.

A pasteboard file for holding this size of card can be obtained at any stationery store, and the cards held together by fasteners can be placed under **subject headings,** ready for access at all times.

No book or article of value should be read without making a note of its **name, subject, author,** and **edition.** (This latter is very important, because in a year or two another edition may have all its pages differently numbered, and even additions and deletions made, so that should you quote such a volume and the one to whom you are quoting, looks up the quotation in another edition, you will be considered not only inaccurate but absolutely untruthful.)

For **clippings**—If you own a periodical in which an excellent article appears, cut it out. Be sure, however, to write upon it immediately the **name** of the paper from which you clipped it, as well as the **year, month,** and **day** it appeared.

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[1]Probably 95 per cent of all you will ever read, you will want to forget, but the remaining five per cent you *will* need, and need badly when the occasion arises.

Until you have a large accumulation, take ordinary long envelopes 4½ x 10½ inches. Fold each clipping and place it in such envelope, writing its title on the upper left-hand corner under the subject like this—

Biology **Frogs** "Different kinds of Frogs."

If you do not own the periodical, make out a **subject-card** just as you would for a lecture, and file it under the proper subject.

For your regular laboratory work you will always have your drawing book. All notes that pertain to the laboratory will be made in that.

II. Students will find that **it is easier not to take notes** on lectures.[1] Many think they will remember more without notes. This is true if the notes are not looked at again; but, if they are gone over from time to time, much that is important will be brought back to mind that would otherwise be lost.

III. Suppose you see an animal, let us say a frog. You must observe:

(1) Its external characteristics.
(2) Its similarities to the human being.
(3) Its dissimilarities to the human being.
(4) Its normal home.
(5) Its method of life.
(6) Its relations to its surroundings.
(7) The conditions under which you came to see it.
(8) Its actions, normal and when disturbed.
(9) Its food and whether it is food in turn for other animals.
(10) How it comes to be where it is?
(11) Whether or not it remains in the same surroundings throughout the year?

This is all studied on the living frog. Every action of a living thing comes under "physiology," which is the science of **functions.** Physiology must, therefore, be studied on the living plant or animal.

IV. In the laboratory you take up the **internal structure,** as well as the **development** of the organism, which means in the case of the frog, how the animal's eggs grow into a tadpole, and this in turn into a frog.

V. You are trying to get a **complete mental picture** of what is known about life and you are trying to get a **gauge** by which to know when a thing is true and when it is not; consequently, you must think of

[1]Of course, each day, after the lecture, the student is to attempt to repeat all that was said in the lecture he has heard, and when he comes to a forgotten point he must consult his notes.

these things you study just as you would if you were trying to use your camera for the taking of the picture instead of your mind.

(1.) Clear away all that is unimportant.

(2.) Choose a subject. In this case **Biology.**

(3.) Have proper **perspective** (that is, have the **relationship** of everything about your subject in proper form, and do not unduly stress any one point). In other words, have you taken **everything** into consideration? For example, you must see to it that some other branch of science does not have some points and conclusions which may destroy yours, for if a single exception can be found in science, it has disproved **the law.**

(4.) You must have sufficient light to make the subject stand forth and be seen clearly. This implies a **proper background**—a background built up in the study of science by ascertaining what has gone before, and what **causes** have produced the particular historical soil upon which the seed of men's ideas have been able to grow. In other words, you must have **all the facts** that can be found if you would have this light throw your subject into the full glare of day. You must exclude shadows as much as possible.

(5.) You must see that your subject is in focus, which means that in any given case, it must stand forth in **sharp relief.** It must not fade away in the distance and become blurred by your prejudices or desires. No vagaries of thought must be permitted. Your reasoning must be clear and definite. Your system of knowledge must be built up **philosophically and logically.**

(6.) You must decide upon how large an opening you will allow your lens; that is, within what narrow limits you are to discuss the subject under consideration.

(7.) You must decide upon the length of time for your exposure, which, in a scientific treatise, means that you must know that **sufficient time has elapsed** to make your experiments valid and positive.

(8.) If you read of the results of others, you must take into consideration the temperamental makeup of the individual writing as well as of yourself and other readers who later pass judgment thereon.

Remember that just as a football player or musician must keep in constant practice, or lose his proficiency, so your brain must have DAILY EXERCISE or it will likewise lose its proficiency.

Remember also, that the man who can, but does not read, has not as high an intellectual ranking as he who cannot read; and he who has the capacity to think, but does not, ranks lower than he who is born without such capacity.

VI. See that your note-book contains complete drawings and descriptions of each of the following subjects for every form studied:

I. ANATOMY

1. **External Makeup.**
2. **Internal Makeup.**

(a)	Digestive	System.
(b)	Circulatory	"
(c)	Respiratory	"
(d)	Excretory	"
(e)	Nervous	"
(f)	Skeletal	"
(g)	Muscular	"
(h)	Reproductive	"

II. PHYSIOLOGY

1. **Processes Pertaining to Food.**

(a) Ingestion (taking in food).

(b) Egestion (throwing out undigested food).

(c) Digestion (fermentation of ingested substance brought about by various secretions).

(d) Absorption (passing of digested food by osmosis through body membranes and making use of inspired oxygen).

(e) Circulation (carrying absorbed substance to all parts of the body).

(f) Assimilation (the conversion of absorbed non-living matter into protoplasm).

(g) Growth (the increase in size due to additional protoplasm being made).

(h) Reproduction (the production of new organisms similar to the parent).

2. **Processes Pertaining to Oxygen.**

(a) Inspiration (taking in oxygen which aerates blood as it passes through lungs).

(b) Oxidation (burning of ingested food).

(1) Secretion (pouring out substances to be used again).

(2) Expiration (throwing out CO_2).

(3) Excretion (throwing out used substances in the form of urea, uric acid, etc.).

(4) Energy
- (a) Applied: Response. Behavior. Locomotion.
- (b) Unapplied: Heat. Light. Electricity.

III. STIMULI

Any of the processes mentioned in this outline may be made more rapid or may be slowed even to the point of complete stoppage by mechanical, chemical, and sometimes by mental **stimuli.**

IV. CLASSIFICATION

(a) Phylum.
(b) Class.
(c) Order.
(d) Family.
(e) Genus.
(f) Species.

V. Finally, remember that your study may be interpreted from any or all of the following points of view:

Both plants and animals must always be thought of when discussing living matter, and both are studied in practically the same manner. But as no one man can study all about plants or animals, or even about everything that pertains to only one plant or animal, scientific men have divided their work into group-studies as follows:

I. **Morphology:** (Gr. morphe=form) Study of Form.

1. **Promorphology** (Gr. pro=first+morphe=form) which treats of General Form.

2. **Anatomy:** (Gr. anatemno=to cut up) the study of organisms by dissection. Usually studied on the dead individual; that is, a study of Structure.

Subdivision

(a) **Gross,** or **Macroscopic** (Gr. macro=large) that which can be seen with the naked eye.

(b) **Microscopic** (Gr. micro=small) embracing the study of the more minute structures with a microscope.

Splanchnology (Gr. splanchnos=organs).
Histology (Gr. histos=web, or tissue).
Cytology (Gr. cytos=cell).
Neurology (Gr. neuron=nerve).

3. **History of Development,** that is, a study of the different stages through which an organism passes from the moment the fertilized cell begins dividing.

Individual Evolution, Embryology (Gr. en=in+bruo=bud).

Ontogeny (Gr. on=existing+genna=to begin), the study of the individual before birth.

Racial Evolution (Phylogeny), (Gr. phylon=tribe) the study of the race.

4. **Teratology** (Gr. teras=wonder) the study of malformations and monstrosities in organisms.

II. **Physiology.** The Study of Functions.

1. **Physiology Proper** (Gr. physis=nature) the functional relation of part to part and to the whole.

2. **Ecology** (Gr. oikos=house) relation of the individual to its whole surroundings, or the study of its environment.

3. **Pathology** (Gr. pathos=suffering) the study of disease. This study also belongs under microscopic anatomy in that disease makes many changes in the actual structure of the cells and tissues.

III. **Distribution.**

In Space (Geographical Distribution, often called **Zoögeography** in so far as it affects animals).

In Time (Paleontology [Gr. palaios=ancient+onta=beings]; also called **Paleozoölogy,** in so far as it affects the study of fossil remains of animals).

IV. **Economic Zoölogy or Botany,** the study of everything living in so far as it touches human welfare.

V. **Classification, or Taxonomy** (Gr. taxis=arrangement+nomos=law), the grouping of plants and animals according to likeness or relationship.

VI. **Psychology** (Gr. psyche=mind or soul), the study of the mind.

VII. **Sociology** (L. socius=companion), the study of animal societies and their relation of each member of the society to the other. This relationship is sometimes said to be due to the so-called Herd Instinct.

VIII. **Genetics** (Gr. genesis=birth), the science "which seeks to account for the resemblances and differences which are exhibited among organisms related by descent."

Individual:
- **Heredity,**
- **Environment,**
- **Education,**
  - Instruction,
  - Einübung or training.

Racial: Archeology (Gr. archaios=ancient), the study of ancient findings to ascertain the cultural state of man at different epochs.

IX. **Biometrics** (Gr. bios=life+metron=measure), the statistical study of life's events or happenings so as to be able to gauge how often these same events are likely to take place in the future.

Summarizing the points that must be kept in mind we may say:

1. You must be able to distinguish between **conspicuousness** and **importance.**

2. You must be able to distinguish between **fact** and **interpretation.**

3. You must be able to distinguish between **principles** and their **application.**

4. You must be able to **discuss all sides** of a subject so as to overcome scientific bigotry and narrowness.

5. You must have a knowledge of type-forms as well as the generalized biological principles which can be drawn from such knowledge.

6. You must be able to apply all the principles you have learned to the human body.

7. You must know (not only memorize) the **meaning** of the scientific words which you are called upon to use. This will be accomplished by **writing in the derivations** of the words in the parenthesis left open for that purpose. All these can be found in the glossary at the end of the volume.

CHAPTER III

THE CO-ORDINATION OF SUBJECTS STUDIED

COMPARATIVELY few students either grasp or understand the value of the various studies laid out for them by college authorities, and it is this lack of grasp and understanding which causes them to slur over much of the subject-matter which it is necessary to know later.

As a starting point for this understanding it is essential that one grasp fully the underlying object of scientific study.

In our smaller cities there used to be exhibited a marvelous clock which had some ten or fifteen dials upon it, each dial recording some important time-element. One, for example, showed the hour of the day, another the time of the rising and setting of the sun, another did the same for the moon, while still another gave the time of the ebb and flow of the tides. There was a dial showing the day of the month, so nicely arranged that even the 29th day of February in leap year would be noted. This clock was so adjusted that there was not only the intonation of a chime every quarter-hour, but several interesting events were recorded at this same time; for instance, a cuckoo announcing the quarter-hour was followed by a rooster strutting forth and crowing, while on the hour, a tiny door at one side of the clock opened, and the twelve apostles solemnly marched across and disappeared on the opposite side, while strangest of all, these apostles did not drag their feet, but actually lifted them as they took their hourly walk.

And all of this elaborate adjustment was the result of a single clock-work running by a single winding.

A living organism is something like that clock, except that it is a thousand-fold more complicated, for man can do many times the number of things that the clock did. Now, the science of Biology is directed just toward the one end of attempting to find what original mechanism makes all these complicated actions possible. In other words, in the study of Biology we are attempting to find not only life's clock-work and the unit structures with which such a mechanism is built, but we also try to approach that particular place or time in the history of the universe when the first winding took place.

Chemistry presents an excellent starting-point for further explanation. In chemistry a compound is analyzed by finding the type of **molecules** that are contained within it, a **molecule** being the smallest obtainable particle of a chemical compound. The molecule, in turn, is then reduced to **atoms** of the various chemical elements, an atom being the smallest obtainable particle of a chemical element. The mind can readily conceive, however, that there are smaller particles than atoms.

As soon as we realize that the black soot which comes from a smoking-chimney and the purest of white diamonds are both composed of exactly the same chemical atoms—that is, are both pure carbon—we find we are not satisfied until some explanation of this remarkable difference can be given.

At this point we must pass to the study of **physics**, for it is physics that deals with the laws of movement and of energy. In reality, it is from the physicist, rather than from the chemist, that we obtain an explanation as to why the different chemical formulæ are what they are. The physicist has found that atoms can be broken up into very tiny particles, each fragment having the power of attracting or repelling other fragments. Such tiny particles are called **electrons**.

Knowing this we can evolve a great underlying principle that can be applied in as many different ways as was the principle of Archimedes, referred to in a former chapter.

In fact, the theory of electrons tells us not only why two elements chemically alike have a totally different appearance, but it also gives us an explanation as to why there are different chemical elements to begin with.

It has been found that if pure carbon is subjected to tremendous heat in electric furnaces, followed by the application of thousands of pounds of pressure, this carbon will become a diamond.

The scientific man, learning that this is true, immediately attempts to bring about a wider application of his knowledge for the purpose of evolving still other principles. Such an one comes to the conclusion, then, that it is quite likely that all matter is composed of electrons, and that the different forms that matter assumes are due only to varying degrees of heat and pressure.

This means that everything physical—everything that occupies space—be it wood, iron, coal, radium, hydrogen, oxygen, or what not—is quite probably composed of the same ultimate material or substance, but in each case such ultimate substance has been exposed to a different quantity of heat and pressure.

Now, the object of science is to **control nature** and to **prophesy what will occur when certain acts are performed.**

It is well to note at this point that science can never explain the fundamental **why** of anything. It cannot tell why metal becomes soft when heated, while an egg becomes hard. What science can do, and aims to do, is to find **how** things can be changed from what they are by performing a combination of certain definite acts.

Just as the explanation of how chemical elements come to be what they are was found by physicists and not by chemists, thus showing the inter-relationship of the two sciences, so man, being a complete entity made up of both the physical and the mental, must be considered in his double capacity if we are to study him scientifically.

Physics and chemistry form man's most important studies on the physical side. Everyone knows that food is composed of chemical substances which, after being taken into the body, pass through many chemical changes while being converted into new blood to keep life going. The student, however, probably does not know that Louis Pasteur, the Father of Bacteriology, was a chemist, and that the whole modern conception of medicine is based on the bacteriological findings he obtained while working on fermentation experiments in the chemical laboratory. The knowledge he there gained was later applied by Lister, who made aseptic surgery possible.

The discovery of oxygen, by a chemist, directly underlies practically every experiment in physiology which can be performed, while the great modern surgical advances are largely due to our ability to anesthetize the patient. The anesthetics used are nitrous oxide, chloroform, and ether—all products of the chemical laboratory.

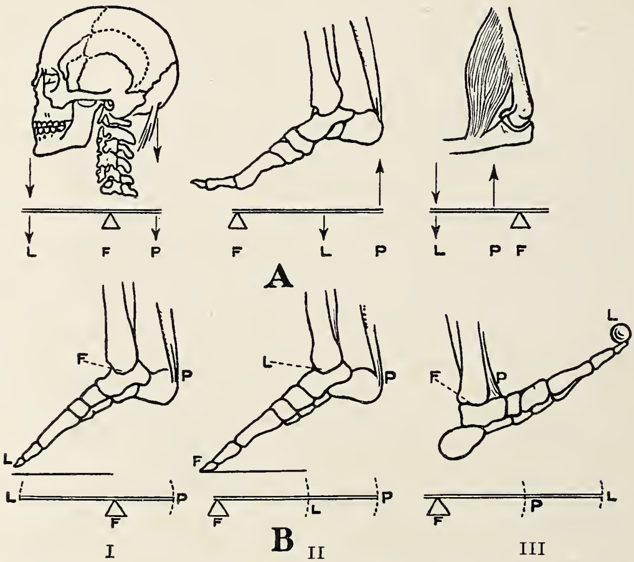


Fig. 2. Diagrams to illustrate the different types of levers in their relations to the mechanical action of muscles.

A. Comparison between head, foot and elbow.
B. Comparison between different actions of foot.

Most muscles act on bones as levers. In physics there are three types of levers recognized. In the first type (I) the fulcrum (F) lies between the place where power (P) is exerted on the lever and the point of resistance or load (L). Levers of this kind are frequently met with in the body. In A, (I) the weight of the skull tends to bend the head forward, while the force exerted by the dorsal muscles of the neck serves to keep the head in position.

In levers of the second class (II) the point on which power is exerted moves through a greater distance than the point of resistance. Speed is thus sacrificed to power. Such levers are rare in the body. An example is the body raised on the toes.

In levers of the third class (III) the point on which force is exerted, moves a less distance than the point of resistance, power thus being sacrificed to speed. This is the most common form of leverage in the body. The example A (III) is that of the elbow. Here the biceps and brachialis muscles are attached only a short distance from the elbow-joint or fulcrum, while the hand is the region on which force is exerted. A movement at the point P through a short distance will cause L to move a great distance.

The ability to analyze any product or portion of the body must lie with **analytical chemistry,** while the study of how to build up new products comes under **synthetic chemistry.** All digestion takes place by enzymes, and the enzymes of the stomach, for example, will not function unless they are placed in an acid medium, such as the gastric juice. Changes in food, or abnormalities of various kinds, may cause an excess of this acid, or may prevent a sufficient quantity of the proper quality being formed—all such changes are chemical.

The study of **physics** in its application to one's body is not so self-evident and is often the bug-bear of students. Unfortunately most text-books on physics lay stress upon mechanical laws only in their industrial applications, and fail to show how these same laws apply to the human body.

The **mechanics** of the living body are, however, quite similar and much more important than all the industrial applications which can be found.

The three types of **levers** with the fulcrum in different positions are the same in the body (Fig. 2) as they are in general mechanics. A knowledge of the exact points where stress and pull are applied, with a consequent ability to "figure out" where new growth-structures will develop, is of prime importance in broken, misplaced, and re-set structures, if the patient is not to suffer untold agony and sorrow in future years.

In this connection, the laws governing **pulleys,** the combination of rolling and sliding movement of joints, as well as the principles of gravity, must be thoroughly understood; for, it is simply and solely on these principles that the various movements of the body can take place, and consequently, it is only a knowledge of such principles which can in turn make possible the correction of abnormalities of joints.

The principles governing **friction** are applied in the correction of both internal and external injuries, while experimental physiology would be impossible without a knowledge of **centripetal** and **centrifugal forces** and the laws governing **liquid and gaseous pressures.**

The laws governing liquids apply throughout the entire body in great detail, for there is scarcely a spot as large as the point of a needle in the body that liquid nourishment (blood or lymph) does not enter. Pressure in any region causes swelling, varicose veins, dropsy, and a host of other ills; while bed-sores are nothing more or less than the effect of continued pressure of blood in the same vessels of the side or back on which the person lies, gravity causing the blood to sink to the lowest level and be held there.

An understanding of the difference in **densities** makes possible many physiological experiments, which would otherwise result fatally to the patient. A solution, if it is to be injected, must not only have the proper density so as not to cause a too rapid change in the blood, but the whole subject of **osmosis, diffusion,** and **capillary attraction** must be understood before such an experiment can be intelligently applied.

The place where parasites are most likely to lodge, is largely determined by the rapidity, direction, and pressure of the blood-stream.

Hydrometers and **urinometers** for testing liquid densities are built on the principles just enumerated.

Air is a gas, and as such comes under the laws governing **gaseous pressure** and **gaseous diffusion.** When it is remembered that the whole process of life is snuffed out when the breathing apparatus ceases to work properly, it will be seen that the aeration of the blood to keep it red and healthy, the working of the lungs under normal and abnormal conditions (the latter in chest puncture), the being overcome by gas, externally or internally, as well as the changes in breathing at different altitudes and at different depths (as on mountain-tops and in submarines); all these can only be understood and helped by a thorough study of the laws and principles applying to gasses.

The principle of the **force-pump** makes the pumping of the heart and the one-way valves in the heart and veins understandable.

All food eaten can only be reduced to blood by a burning process, called **oxidation.** Unless the principles governing heat are understood, the processes of digestion and the consequent abnormality—indigestion—must go on unremedied.

The principles of **ventilation** in the home, office, work-shop, or sick room, make for health or disease, just as one applies them or leaves them unapplied. A window opened at the top warms the incoming air before it strikes the patient. The knowledge that warm air ascends and cold air descends suggests that a heating plant must be placed in the basement and a cooling plant in the attic. The principle of **evaporation** explains how outpourings of the sweat glands, by being drawn off rapidly into the surrounding atmosphere, make it possible for warm-blooded animals to retain an even temperature, regardless of varying environment.

In "chills" the body really produces more heat than ordinarily, but it is the heat-regulating apparatus which is out of order.

Thermometers and **hygrometers** are measuring instruments by which we note the amount of heat and moisture respectively in the atmosphere. They are, of course, simply applications of laws learned in physics.

Then, too, **boiling and sterilizing** make food, which is normally unpalatable and sometimes even injurious, palatable and non-injurious. It is sterilization also which makes antiseptic surgery possible.

The laws governing liquids under varying conditions of heat give us the basis for understanding **evaporation, condensation, distillation, conductivity, convection, radiation,** and even **plumbing and heating.** It explains why germs can be killed at a much lower temperature when there is moisture in the air (steam) than otherwise. In fact, a human being can live in a boiling-point temperature if the air is dry, but he cannot live in anywhere near so high a temperature if there is moisture.

The entire understanding of the working of the ear is a matter of physics, in that "sound" is a branch of that science. And, as the larynx is the instrument through which our vocal sounds are produced, this, too, must be studied in the light of physics.

All knowledge of the eye, such as our ability to fit glasses, operations for ocular defects, and all the instruments with which the modern oculist examines and remedies eye-troubles, are the result of direct applications of the principles of "light," which, like "sound," is a branch of physics. Any assistance in improving hearing or sight must, therefore, be looked for only in the laws of physics.

The microscope, without which practically none of our modern scientific work would be possible, is the direct application of the laws found in physics, and there cannot be a single improvement in that instrument until a new principle of physics is discovered.

Likewise, the microtome, the instrument by which we are able to cut minute sections for the microscope, could not cut with precision the thin slices that it does (1/25,000 of an inch in thickness), if it were not made in accordance with the laws of physics.

Electricity, used so much now in the treatment of disease, the x-ray, the fluoroscope, and radium — all these come under the science of physics.

That same science explains why the blood-platelets gather along the blood-vessel where the blood stream is slowest; it explains how **coagulation** is thus assisted so that we do not bleed to death when wounded; it tells us why one can crawl over thin ice when walking across the same ice-sheet would be impossible; why we can safely crawl on the floor in a room filled with smoke, when standing erect would be fatal; it makes an intelligent understanding possible of how to drain wounds; it tells us why water-pipes burst when the water in them freezes; it tells us why a quilt or comforter of cotton is warmer than a woolen blanket; it tells us why men's voices are different from those of women's, and why the pupil of the eye can accommodate itself to changing distances and intensity of light. And, just as it tells us that an electric bell will not ring until the proper connection is made, so it makes possible the locating of lesions in the body by noting where nerve connections are functioning properly and where they are not.

Probably the **mathematical sciences** may seem somewhat remote from the study of life in general, yet **calculus** is needed in the study of physical chemistry, and the laws of **refraction** in the fitting of glasses. The relationships of structure in the body must be studied both as to their **quantity** and **quality.** The various names given to the different forms and shapes of the parts of the body are largely taken from **geometry.**

Surely so remote a subject as ancient **Greek** is far removed from modern scientific study, and yet the student need but turn to the glossary of this book, and go over the names there given, to see that ancient Greek is not only valuable, but essential; for, practically every name of plants and animals comes from the Greek, and unless the **meaning** of the word itself is known, the entire subject-matter becomes mere memory work.

The reason each student must draw a picture of what he sees in his laboratory experiment, is to force him to observe so well and so accurately that he can make so accurate a drawing of a structure that another may in turn recognize the object from the drawing. Drawing a picture of what he sees also forces the student to keep the subject in mind for a greater period of time than would otherwise be the case, and gives him a definite graphic mental picture of what he has seen.

A knowledge of **English** makes it possible for the student to present a word-picture of the same matter that the drawing presents. **A description** is, therefore, demanded of the student in addition to the drawings, thus again causing him to call to mind all that he has seen and noted. This not only means that the repetition will cause him to remember the subject-matter the better, but it means that he learns to do that particular thing upon which much of his future reputation as a professional man depends, namely, to prove to others in clear and telling language what he knows.

The mere gathering of facts is of no more value than the mere gathering of bricks. The important thing in science is to be able **to coördinate the facts** one finds, and to read into these facts their real **meanings.** Meanings, however, require the use of the intellect, and the laws which govern the intellect are embodied in that branch of study called **philosophy.** The most important philosophic studies for the scientific student are **logic, psychology,** and **ethics.**

Every valid conclusion which anyone may form must be built up logically. Logic is merely **the grammar of reason.** In fact, every diagnosis that a medical man makes, must be built entirely upon logic if it is to be worth anything, or to stand the test of truth.

The study of the way in which the mind works is called psychology, and a man cannot intelligently study and clearly understand any of the abnormal workings of the human mind, unless he first knows the normal. He can know little about mental or nervous diseases unless he knows the way in which the mind works when it is not diseased. In his study of **neurology** the medical student follows the various nerve-tracts of the brain and spinal cord, but he cannot understand the real meaning of these nerve-tracts unless he knows the principles of psychology. He will become a follower of fads and fancies while he misses the underlying truths and facts which the real scientific man should have.

From the philosophical realm we obtain the validity of our ethics. Ethics is the **science of conduct.** We know that holding an air-breathing animal under water will drown it. And just as death to the animal follows such an act, so, too, many of our acts bring a definite punishment of some kind with them. It is to know what acts bring punishments, so as to know what acts to avoid, which is the distinct province of ethics. In other words, it helps us to arrange a definite "philosophy of life" for ourselves.

And lastly, one or two **modern foreign languages** should be known in order that we can the better obtain various angles and other points of view, for there are many possible explanations that the same facts may seem to prove. One has but to read through any ordinary textbook of science to find quoted there an overwhelmingly large number of foreign names and papers. This means that no one can deem himself a master of his subject unless he knows at least many of the thousands of observations which have been made by the great scientific minds of other lands. Unless he knows this, he is bound to spend a large part of his life in the attempt at proving or disproving many things which have already been proved or disproved by others. He is wasting the time which should be given to more valuable work.

From what has been said above it will be seen that practically **all the sciences must be studied to throw light on the different workings of the body.**

At this point it is necessary for the student to grasp the fact that every living thing must be considered as a complete unity, and that every organ and every part of an organ which a living thing possesses, is definitely connected to, and with, every other part of the body.

One may suffer from headaches, or eye-trouble caused by displaced bones in the feet, which in an indirect way press against nerves connecting with the head; or, one may have a backache or earache, or even rheumatic difficulties, due to ulcers beneath the teeth.

It is for reasons such as these that it is necessary for the dentist, as well as the oculist, to study Biology, and to learn the unity of the living being. For there is no more reason for a student of dentistry to confine all his study to the teeth alone, or an oculist to the eye alone, than it is for a nerve specialist to study the nerves alone. Any such one-sided study leaves out of consideration the most important factors necessary to a legitimate diagnosis. And, with a wrong diagnosis, the treatment is bound to be wrong, or at most, mere guess-work.

It is well also for the student to bear in mind that, though he may not immediately see the relationship of some things to the general course he is taking, it does not follow that such relationship does not exist. One can learn to start and stop a locomotive in twenty minutes, but this does not make one an engineer. It takes years to do this. It is not when all things go well that the expert is called in, but when things go wrong. This is just as true of the engineer as it is of the physician, the dentist, the lawyer, and other professional men. And it is only he who knows the relationship of all the parts, who can hope to become an expert.

In conclusion, the student should remember that college courses are arranged on a **minimum basis.** That is, the work laid out for the student is the **least amount of work he can do and yet obtain a passing grade.** It is, therefore, only **the student who actually does more than is required, who deserves any credit worth mentioning.**

CHAPTER IV

THE FROG

THE frog lends itself to laboratory work in Biology probably better than any other animal. It is sufficiently common to be somewhat familiar to the student, and it can be obtained practically at any season of the year. It is a **vertebrate** (Latin—**vertebratus**=jointed), which means it has a back bone, and an **amphibian** (Greek—**amphi**= both+**bios**=life), meaning that it lives a double life. This latter statement refers to the animal's inability to live either on land alone, or entirely submerged in water. This inability to live entirely in the air or in water is well shown by the fact that, if the frog's skin becomes dry, as it does when the animal is away from water and in a dry atmosphere, the animal dies, because the skin is then no longer capable of serving as an organ of **respiration** (L. **re**=back+**spiro**=breathe). Contrariwise if it be constantly immersed in water, it will also die, because it must breathe air.

The particular **species (Rana pipiens)** that we are describing (though any other of the common forms would answer the same purpose) is found in or about fresh-water lakes, ponds, or streams. The species is fairly well distributed over the entire North American continent, except the Pacific slope.

Everyone has noticed the longer and stronger hind legs of the frog, and the squatting position it assumes on land, as well as the rapidity with which it leaps into the water when disturbed along the banks. If one observes it while in water that is beyond its depth, it will be noted that the hind legs hang out straight and the tip of the nose is exposed to the air. Should it be disturbed while in this position, the hind legs are **flexed** (L. **flecto**=bend), which throws the body downward. The fore legs are used in arranging the direction in which the animal will go; the hind legs are then **extended** (L. **ex**=out+**tendo**=stretch), completing the movement which forces it forward.

Everyone also knows the sound of croaking frogs at night, especially when the atmosphere becomes damp, though it is not so generally known that the frog croaks far more frequently during the breeding season than at other times. The croaking can be accomplished both in and out of the water. The croaking under water is produced when the air from the lungs is forced past the **vocal cords** into the cavity of the mouth, and then back again into the lungs.

There is another reason why the frog may be considered as leading two lives, (Fig. 3) beside the fact that it needs both air and water, and that is that it lives a different **type of life when young** than when grown. This comes about as follows: The eggs of the female frog are practically always laid in water and hatched there. Little tadpoles develop from these eggs and breathe by **gills** in the **larval** ( )[1] condition. Some species of frogs retain these gills all through life, even though **lungs** may be present in the adult forms. The tadpole gradually develops into the mature frog, losing its tail and developing the long hind legs and the short fore legs so familiar in the adult animal.

EXTERNAL FEATURES

It is essential that one examine quite carefully the **external structure** of any plant or animal one may wish to study; for, unless this knowledge is borne in mind, **internal structure** cannot be **interpreted** correctly. It is well also to keep in mind our own bodies, and to observe similarities and differences wherever they may occur in animals and plants.

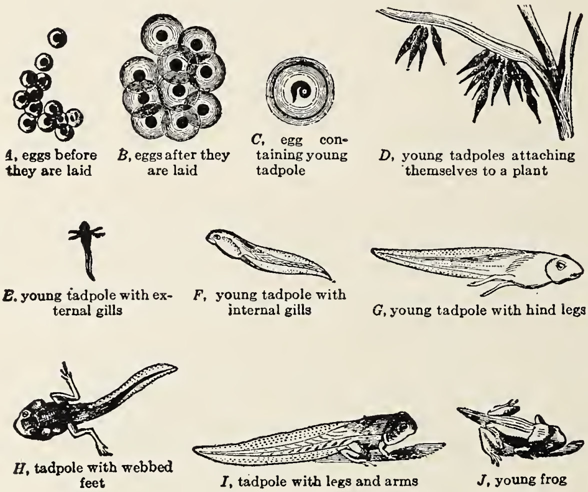


Fig. 3. Eggs, Tadpole, and Adult Stages of Frog. (After Brehm and other authors.)

It will be noted immediately, that the frog has no neck. The head is broadly united to the **trunk.** The eyes protrude somewhat, but can be withdrawn readily into the **orbits.** A pressure put upon the eyes, when the mouth of a frog is open, will extend the **inner membrane lining** of the **roof** of the mouth quite prominently, showing that the orbit, or eye socket, is not separated from the mouth by any bones of the skull as in man. The dark oval opening of the eye, the pupil, is surrounded by the **iris**, a more brightly colored ring. There are upper and lower lids, the upper one moving but slightly, the lower one thin and transparent, and capable of covering the entire eye. This lower eyelid is different from that of most animals, and this type of lid will be met with again in other animal-forms to be studied. The **nictitating membrane** ( ) is separated from the lower lid (Fig. 4), but

[1]The empty parentheses are to be filled by the student, with the derivation of the word as found in the Index-Glossary.

appears to form a continuation. In birds, for example, this membrane is also very thin and can be thrown over the eye from the **inner angle** of the orbit. Behind the eye is a more or less circular area called the **tympanic membrane,** ( ) which covers the **ear drum.** There is a slight **prominence** in the center of this membrane produced by one of the small bones called the **columella** ( ). This bone connects with the **inner ear,** and, when any sound-wave strikes the tympanic membrane, the vibrations are communicated through this bone into the internal ear. This gives rise to the **sensation of hearing.** On the inner side of the tympanic membrane we find a little cavity known as the **Eustachian tube** ( ), which opens internally into the mouth. There is no **external ear** as in man.

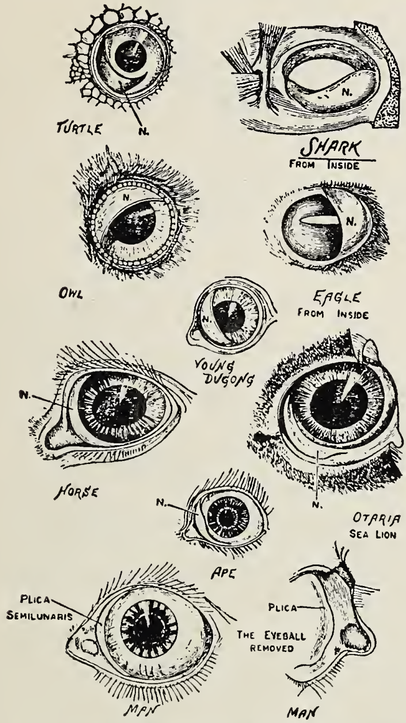


Fig. 4. Examples of Nictitating Membranes. (From various authors.)

The two openings immediately **above** and **behind** the tip of the nose are called **nostrils** or **external nares.** Sometimes in **front** of the eyes there is a little light area known as the **brow-spot.** This was connected with the brain in the **embryo** ( ). The brow-spot is a feature of considerable interest from the fact that in the **embryonic development** of the frog, it connects with a peculiar **outgrowth** of the brain known as the **epiphysis** ( ) or **pineal gland.** This is supposed to be a **rudiment** ( ) of a stalk which formerly connected with the **medial eye** ( ) which still persists in certain forms of **reptiles** (Fig. 5) ( ). The nostrils are guarded by **valves** which open and close during **respiration.**

The mouth extends from one side of the head to the other, and the **anus** ( ) is situated at the **posterior** ( ) end of the body. The **fore limbs** are divided into an **upper arm,** a **fore arm,** and a **manus,** ( ) or hand, the latter possessing four **digits** and the so-called **thumb,** a **rudiment** of the fifth. In the male the **inner digit** is thicker than the corresponding one of the female, especially during the breeding season. The entire fore arm is also relatively thicker in the male than in the female.

The hind limbs are well **adapted** for jumping and swimming. These are divided into three portions. The upper portion is known as the **thigh**; the middle, the **crus** or **shank**; and the distal ( ) portion, the **foot** or **pes.** The foot, which is well developed, has five toes and the rudiment of a sixth, called the **prehallux** ( ), situated on the inner side of the foot. The toes themselves are connected with a web, making the foot quite efficient as a swimming organ. There are also small **cushions,** called **subarticular pads,** ( ) between the bones of the toes.

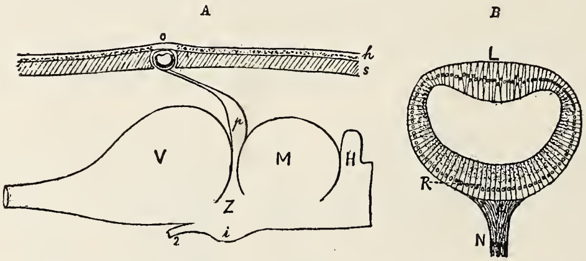


Fig. 5. Pineal eye of a Lizard; diagrammatic. *A* brain and upper wall of the skull, the latter cut through; *B,* pineal eye alone, in section. *V, Z, M, H,* cerebrum, thalamencephalon, optic lobes, cerebellum; *h* skin, *s* roof of skull, *o* unpigmented portion of skin below which the pineal eye lies in a hole in the roof of the skull; *p* epiphysis, *i* hypophysis, 2 optic nerve. *L* lens, *R* retina, *N* nerve of pineal eye. (After Boas.)

The skin is smooth and loose, containing large black **pigment spots** ( ) and some green and golden pigments as well. As with other **vertebrates,** the skin has two layers, an outer called the **epidermis** ( ) and an inner, the **dermis** ( ). Nothing similar to **hair** or scales can be found on the frog. In the skin there are large **mucous glands** ( ) which keep the surface slimy, and there are also some **poison glands secreting** ( ) a whitish fluid, supposedly for **defensive** purposes. Behind the eyes there are usually two light colored **ridges,** formed by a thickening of the skin and called the **dorso-lateral dermal plicae** ( ) or folds. There may be some smaller, **irregular, longitudinal folds** ( ) of skin between these. It will also be observed that the color of the skin is much darker on the upper, or dorsal, surface than below, where it is almost white.

INTERNAL STRUCTURE

As with man, the various **organs** ( ) and **tissues** ( ) of the frog's body are supported by an **internal skeleton** of bones. This is called an **endoskeleton** ( ) to distinguish it from the skeletons in such types of animals, as the **crayfish,** which have their entire skeletal structure on the **outside of the body,** forcing that animal to grow an entirely new skeleton whenever the animal itself grows larger than its skeleton jacket will stretch. The higher forms of animals all have endoskeletons. The different parts of the body are moved by the action of **muscles**, which in turn are **innervated** ( ) by nerves. To know the **internal structure** of an animal one must know all that can be known in regard to the following systems:

1. The Digestive System.
2. The Circulatory System.
3. The Respiratory System.
4. The Excretory System.
5. The Nervous System.
6. The Skeletal System.
7. The Muscular System.
8. The Reproductive System.

After an **incision** is made along the **mid-line** (Fig. 6) of the **ventral** ( ) **surface** of the animal from the **lower angle of the jaw** to its most **posterior end**, and the skin-coverings are pulled aside, the internal organs are seen. These are called the **viscera** ( ). The cavity in which they are found is known as the **coelom**, ( ) or **body cavity.**

If the animal has just been chloroformed, the **heart** will still be beating. The heart is contained in a sac-like structure called the **pericardium** ( ).

Surrounding at least a portion of the pericardium, are three prominent **lobes** of the **reddish-brown liver**, while the **lungs**, looking like small strawberries, lie, one on each side, near the **anterior** end of the **abdominal** cavity.

The **stomach** and the coiled intestine attached to it, are easily recognizable.

The **kidneys** are **flattened reddish bodies** attached to the dorsal body wall.

If it is the breeding season, and the frog is a female, almost the entire body-cavity may be filled with thousands of **eggs.** The eggs in turn are contained in a **film-like covering** known as the **ovary** ( ) and **oviducts** ( ), the latter organs serving as tubes through which the eggs leave the body. If the specimen is a male, the two **testes** ( ) will be suspended by little **membranes** at the side of the **digestive canal** (t, Fig. 6). The entire lining of the abdominal cavity in all the higher forms of animals is called the **peritoneum** ( ). When one or two layers of this peritoneum **suspend**, or hold up an organ, such as the digestive canal and the reproductive organs, such suspending peritoneum is called a **mesentery** ( ).

THE DIGESTIVE SYSTEM

It will be noticed that the tongue is **extensile** ( ), that is, it can be thrown forward and outward. On the tongue there is secreted a sticky substance which causes objects with which it comes in contact to adhere. It is interesting to know that unless an object is moving, the frog pays no attention to it. The **mouth** or **oral opening** is relatively large. The opening on the interior is called the **buccal**

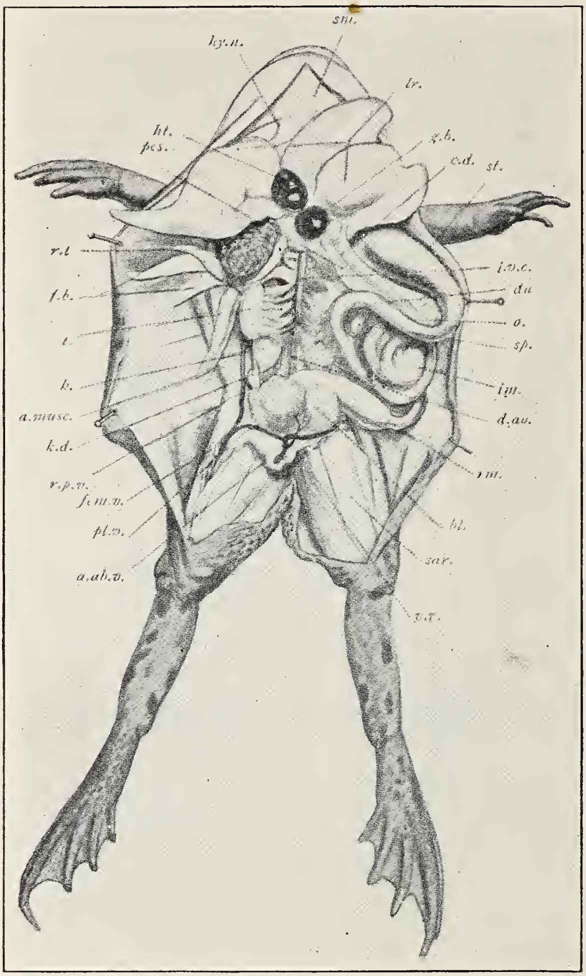
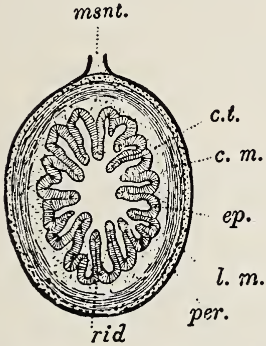


Fig. 6. A Male Frog Dissected from the Ventral Side.

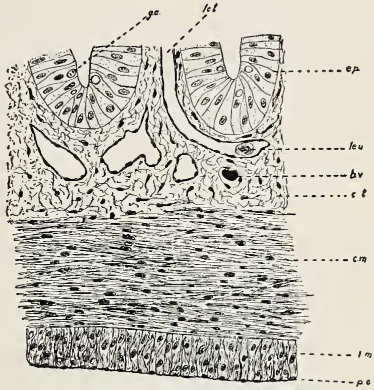
a.ab.v., Anterior abdominal vein, cut short, ligatured, and turned back, *a.musc.*, cut edge of abdominal muscles; *bl.*, urinary bladder; *c.d.*, common duct of gall-bladder and pancreas; *d.ao.*, dorsal aorta; *du.*, duodenum; *f.b.*, fat body; *fem.v.*, femoral vein; *g.b.*, gall-bladder; *ht.*, heart; *hy.n.*, hypoglossal nerve; *im.*, ileum; *i.v.c.*, inferior vena cava; *k.*, kidney; *k.d.*, kidney duct with vesicula seminalis; *lr.*, liver; *a.*, point at which *c.d.* enters the duodenum; *pcs.*, pancreas; *pl.v.*, pelvic vein; *r.l.*, right lung; *rm.*, rectum; *r.p.v.*, renal portal vein; *sar.*, sartorius muscle; *sm.*, mylohyoid muscle; *sp.*, spleen; *st.*, stomach; *t.*, testis; *v.v.*, vesical vein. (After Borradaile.)

( ) cavity. There are teeth on the **maxilla** ( ), **premaxilla** ( ), and **vomer bones** ( ). These assist in **holding,** but not in **masticating** the food. Immediately back of the tongue on the **floor** of the mouth is a narrow slit called the **glottis** ( ) leading to a tube[1] passing to the lungs, and directly behind the glottis, a larger opening is found, leading to the **oesophagus**, which empties into the stomach. The stomach itself is **crescent-shaped**, lying mostly on the left side of the body. The larger anterior portion is called the **cardiac end** ( ), while the **constricted** or posterior portion, meeting with the intestine, is known as the **pyloric** ( ) end.



A. A Diagram of a Transverse Section Through the Ileum of a Frog.
c.m., Circular muscle layer; *c.t.*, submucosa; *ep.*, epithelium which lines the gut; *l.m.*, longitudinal muscle layer; *msnt.*, mesentery; *per.*, peritoneum; *rid.*, longitudinal ridges of ileum composing mucosa.

Fig. 7.



B. A Portion of the Section Shown in A, More Highly Magnified.
b.v., Blood vessel; *c.t.*, connective tissue of mucous membrane or submucosa; *c.m.*, circular layer of muscle fibres; *ep.*, epithelium; *g.c.*, goblet cell; *l.m.*, longitudinal layer of muscle fibres; *lct.*, "lacteal" or lymph vessel of the intestine; *leu.*, leucocyte or lymph corpuscle; *p.e.*, peritoneal epithelium. (After Bourne.)

The first portion of the intestine, a sort of U-shaped band, is known as the **duodenum** ( ). The several coils following it are the **intestine** proper. This intestine finds its way into a large, short chamber known as the **rectum**, which in turn communicates with the **exterior** through what is called the **cloacal** opening ( ). The walls of the stomach are composed of five layers (Fig. 7), the outer portion quite thin, called the **peritoneum**; then two **muscular layers**, the outer called the longitudinal, and the inner the circular muscle layer, followed by a **spongy division** called the **submucosa** and an **inner folded mucous layer**, the **mucosa** itself. This latter is made up of **glands** lying in **connective tissue.** These glands are longer at the cardiac than at the pyloric end. The inner layer of the intestine, the mucosa, is considerably folded and consists of **absorptive and goblet cells.** The **urinary bladder**, the **reproductive ducts**, and the rectum open into the cloaca.

[1]This tube to the lungs is a part of the respiratory system; consequently the opening, the glottis, really does not belong to the digestive system, but it is mentioned here because the student will see it while noting the surrounding structures and it is well for him to know all related parts of a given region.

The **digestive glands** themselves are the **pancreas** and **liver,** the former lying immediately **between** the **duodenum** and the **stomach.** The pancreas is a much branched **tubular gland,** secreting an **alkaline** digestive fluid. It empties into the **common bile duct.** The three-lobed liver also secretes an alkaline digestive fluid, known as **bile.** This is carried by the little **bile capillaries** into the **gall bladder** where it is stored until food enters the intestine, when it passes into the duodenum through the common bile duct. Digestion begins in the stomach.

According to Latter, "the alkaline fluid secreted by the mucosa layer of the oesophagus and the **acid gastric juice** secreted by the glandular walls of the stomach digest out the **proteid portion** of the food by means of a **ferment,** ( ) called **pepsin,** which changes proteids into **soluble peptones.** The food then passes through the pyloric constriction into the intestine. Here it is attacked by the **pancreatic juice** and the bile. The pancreatic juice contains three ferments: (1) **trypsin,** which converts proteids into peptones; (2) **amylopsin,** which converts starch into sugar; and (3) **steapsin,** which **splits up fats** into **fatty acid** and **glycerin.** The bile **emulsifies fats** and converts **starch** into **sugar.** The intestinal wall produces a secretion which probably aids in converting starch into sugar.

"**Absorption** begins in the stomach, but takes place principally in the intestine. The food substances, which have been dissolved by the digestive juices, are taken up by the mucosa layer, passed into the **blood**

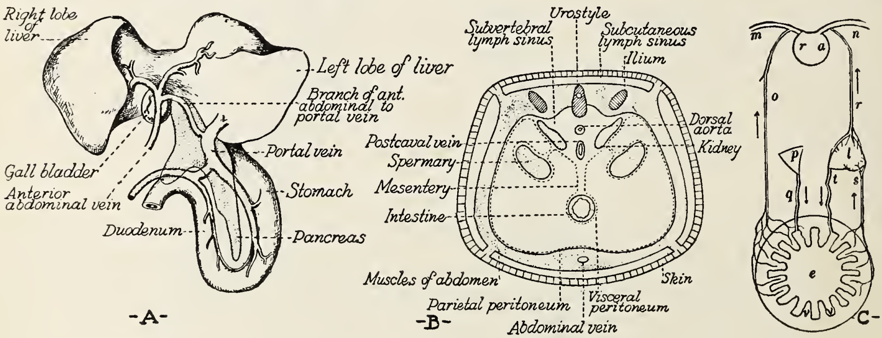


Fig. 8. Diagrams of Important Relationships.

A. The relation of the hepatic portal system to the stomach, intestine, pancreas and liver.

B. Diagrammatic transverse section through the abdominal region of a frog.

C. Diagram of the two main channels by which food enters the general circulation in mammals. *e,* intestine with villi; *r a,* right auricle of the heart; *m,* postcava; *n,* precava; *o,* thoracic lymph duct; *p,* pancreas; *q,* pancreatin duct; *s,* portal vein; *t,* bile duct from *l,* liver; arrows indicate the course of secretions entering the intestine, and of the absorbed food departing therefrom.

(A, after Howes; B, after Parker; C, from Needham's *General Biology,* by permission of The Comstock Publishing Co.)

and **lymph,** ( ) and are **transported** to various parts of the body (C, Fig. 8). The undigested particles of food pass out of the intestine into the cloaca and are then discharged through the anus as **faeces.**"

The absorbed food is used by the frog to build up new **protoplasm** to take the place of that consumed in the various life activities, and to increase the size of the body. Food is stored up in the liver-cells as **glycogen, a carbohydrate** similar to starch and often called "**animal starch.**" The absorbed food is conveyed to the liver by the portal vein and is there converted into glycogen, pending the demands of the general tissues of the body. As occasion rises, it is converted into more soluble material, a sugar, and sent into the main bloodstream via the hepatic veins and inferior vena cava. Fat globules are also contained in the liver cells. The storage function of the liver is one of considerable importance, especially during hibernation and in the breeding season; the weight of the organ exhibits a well-marked seasonal variation in accordance with the amount of reserve food contained. The details of this phenomenon have been worked out by Alice Gaule in **Rana esculenta.** The breeding season of this form is in May, June, and July. The table shows the average weight of the liver in the two sexes month by month.

"It will be observed that the liver is most depleted in both sexes in June, the middle of the breeding season, and that it reaches its maximum weight in September when the system has recovered from the exhaustion of spawning. Throughout the winter the reserves are being steadily used up, with no recovery by the female, the average weight of whose liver is greater than that of the male, but with a slight recovery in March and in May by the male. It is probable that this general difference depends upon the fact that the ovaries of the female make a great and continuous demand upon her system throughout the whole period of maturation, so that in spite of renewed feeding in the spring there is no recuperation in the liver. In the male, however, there is no such continuous drain but rather a sudden call upon the reserves at the actual time of pairing—a call due not only to the discharge of the spermatozoa but also to the muscular exertions of the male at that season. This call is marked in vigor by the sudden reduction of the liver to rather less than half its weight in June.

Month	Weight of male liver	Weight of female liver
January	10 grms.	13 grms.
February	10	12.5
March	13	11
April	10	10
May	12	9
June	5.5	7.5
July	7.5	11
August	6	12
September	22.5	27
October	18	25
November	22	25
December	18	22

"Reserves of food are also laid up in the fat-bodies. These have no direct connection with the digestive system, but may conveniently be dealt with here. They are bright yellow, finger-like bodies grouped in front of the testes or ovaries as the sex may be. They develop from the anterior portion of the genital ridges whose posterior portions alone give rise to the sexual organs. In the autumn they are of great size and loaded with fat-cells, a certain amount of lymphatic tissue being also present. In the spring they are much reduced. It is probable that they also perform other functions at all seasons of the year, but on this point we have no precise knowledge."

GLANDS

Glands may be conveniently classed into two groups:

Exocrine glands, that is, glands whose product are used externally or on substances entering the body, and which generally leave by way of ducts.

Endocrine glands, that is, glands whose products act on the body itself, not on substances brought into it. This type of gland generally has no duct; or if so, as in the case of ovaries and pancreas, the "endocrine" portion of the secretion is absorbed by the blood vessels and does not leave the gland by way of a duct. The term "ductless glands" has been used to designate these glands, but has been found inappropriate. The products of the endocrine glands are known frequently as **"internal secretions,"** and are composed of active agents similar to enzymes. The name of **"hormone"** (excitant) has been given to these agents, which differ from enzymes primarily in that their activity is not destroyed by boiling.

It has been found, however, that the action of the endocrines may be both **stimulatory** and **inhibitory,** as, for instance, in certain experiments on tadpoles which were fed with thymus and thyroid gland. Gudernatsch (1912-14) found that the thyroid food stimulated development and inhibited growth, while thymus stimulated growth and inhibited development. Thyroid-fed tadpoles matured in four weeks, as contrasted with the normal period of twelve weeks, but were dwarfs and pigmies in size; while thymus-fed tadpoles were gigantic in size, but after sixteen weeks showed no indication of transformation, in fact, had not yet developed their hind legs. From certain other experiments on the sexual glands, it has been similarly concluded that the internal secretion from the sex glands (specifically that of the interstitial cells) acts both as a stimulant to the body so that it will develop the characteristics pertaining to its proper sex, and as an inhibitor in suppressing those of the other sex. The excitant has been named **hormone**; the inhibitor, **chalone.**

The products of the various endocrines are regulatory in nature, and control or affect such processes of the body as growth, puberty, secondary sexual characters, blood pressure, metabolism, distribution and concentration of substances, muscle tone, blood sugar, etc. Instincts, emotions, mental and psychic states are stimulated, inhibited and complicated by endocrine action.

The two **thyroid glands** are situated on either side of the **hyoid**, and secrete quite a quantity of iodin. In man, their atrophy is associated with the disease called **cretinism** ( ) where certain parts of the body, such as the head, may become very large. Cretins are almost always idiots.

The two **thymus glands** ( ) lie one behind each tympanum. They are small and oval in shape, usually reddish in color, and are placed directly beneath the **depressor mandibular muscle.** The thymus, like the thyroid, diminishes in size with age.

The **adrenal bodies** ( ) are little bands of a yellowish color extending along the mid-ventral surface of the kidneys. They secrete **adrenalin**, a substance necessary for the life of the animal. This substance is used to a considerable extent in medicine at the present time as it will cause a contraction of the blood vessels and raise the blood pressure after injection. However, a little later a reaction sets in, and a lowering of blood pressure follows.

The **spleen** ( ) is a reddish organ lying immediately dorsal to the anterior end of the cloaca. It is supposed to act as a sort of filter for the blood. The old corpuscles are destroyed and new colorless ones are formed. It must be remembered that all that is known in regard to the ductless glands demonstrates that they are of vital importance, but that no absolute conclusions can be drawn as to definite functions of any of them; for, while one or two of their functions are known, there are probably many more functions that are not yet dreamed of.

THE CIRCULATORY SYSTEM

It is essential that the student grasp the fact that there are several **types** of circulation. The **systemic proper** is that closed system of blood vessels by which the blood leaves the heart and passes through the large arteries into the capillaries to carry nourishment to every point in the body (Fig. 9). These **arterial** capillaries then meet with the **venous** capillaries, and waste-matter is collected in the blood and carried by the veins into two anterior and one posterior **venae cavae** by which the blood is returned to the heart.

The heart itself, however, must have blood vessels carrying nourishment to the heart-walls just as an engine run by steam and supplying water to different parts of a building, must have water supplied to its own boiler in order that the steam, which gives the engine its power, may continue to be generated.

The heart muscle, which is the engine of the body, must similarly have a supply of blood to its own walls in order that the heart may be able to pump the blood to all parts of the body after it has entered the heart from the lungs where it was **aerated.** The blood sent to be aerated forms the second type, or **pulmonary circulation.** The digested food which the individual has absorbed must now be taken into the blood and be made a part of that blood, so that there is a replacement of lost substances. This explains why the blood, which goes to the digestive tract by the **coeliac axis,** passes through **two series of capillaries before returning** to the heart:

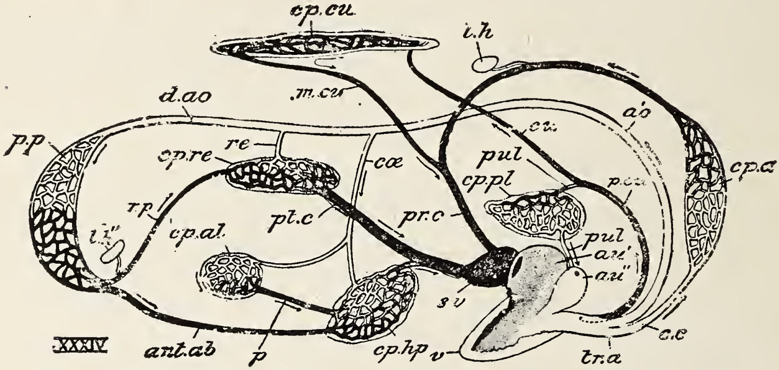


Fig. 9. Diagram Representing the General Course of Blood in the Frog and the Principal Sets of Capillaries *(cp)* Through Which the Blood Flows.

The vessels through which impure blood goes are dark, while those carrying pure blood are left unshaded. The arrows indicate the direction of blood flow. *ant. ab,* anterior abdominal vein; *ao',* aorta; *au',* right auricle; au'', left auricle; *c.c,* common carotid artery;*cœ,* cœliaco-mesenteric artery; *cp.a,* anterior systemic center; *cp.al,* alimentary center; *cp.cu,* cutaneous center; *cp.hp,* hepatic center; *cp.p,* posterior systemic center; *cp.pl,* pulmonary center; *cp.re,* renal center; *cu,* great cutaneous artery; *d.ao,* dorsal-aorta; *l.h',* anterior lymph heart *l.h'',* posterior lymph heart; *m.cu,* musculo-cutaneous vein; *p.* hepatic portal vein; *p.cu,* pulmo-cutaneous vein; *pr.c,* precaval vein; *pt.c,* postcaval vein;*pul,* pulmonary vein; *re,* renal artery; *rp,* renal portal vein; *s.v.,* sinus venosus; *tr.a,* truncus arteriosus; *v,* ventricle. (After Howes.)

First, into the capillaries of the intestine where it receives the nutriment absorbed from the food. Then, after being collected into the large portal vein, it enters the liver.

Second, after entering the liver, the portal vein breaks up into another system of capillaries within that organ.

After the blood has passed through the liver, this second set of capillaries unites to form the **hepatic vein** which empties into the large posterior vena cava leading to the **sinus venosus.** This whole system, where veins break up into capillaries but are again united to form a second vein, is called a **portal system.**

Part of the blood which goes to the legs also has a double system. First it enters the capillaries in the leg muscles. Then on its way back it passes through the kidneys where it is broken up into capillaries. The blood which takes this route returns from the leg through the **renal-portal vein,** while the rest of the blood from the legs is diverted to the **abdominal vein** which passes through the liver (but not the kidneys) on its way to the heart.

Now, just as the heart must have an arterial supply of blood to its own walls in addition to that which it pumps from its cavities, so the liver and kidneys must also have their own supply of blood to feed

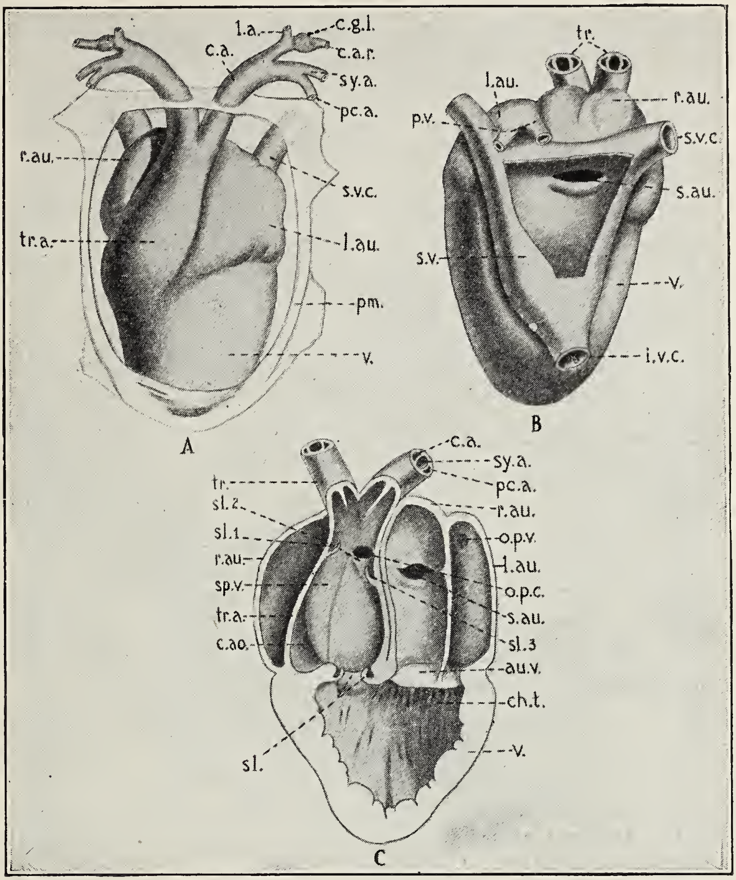


Fig. 10. The Frog's Heart.

A, seen from the ventral side; B, from the dorsal side; C, heart opened and viewed from ventral side. (The ventral wall of the truncus, ventricle, and auricles has been removed.)

A. *c.a*, carotid arch; *car*, carotid artery; *c.gl*, carotid gland; *l.a*, lingual artery; *pc.a*, pulmocutaneous arch; *pm*, pericardium; *r.au*, *l.au.* right and left auricles; *s.v.c*, superior vena cava; *sy.a*, systematic arch; tr.a, truncus arteriosus; *v*, ventricle.
B. *i.v.c.*, inferior vena cava; *p.v.*, pulmonary veins; *r.au.*, *l.au.*, right and left auricles; *s.au.*, opening from sinus to right auricle; *s.v.c.*, superior vena cava; *s.v.*, sinus venosus; *tr'.*, branches of truncus cut across; *v.*, ventricle.
C. *au.v.*, Auriculo- ventricular valves; *c.a.*, carotid arch; *c.ao.*, cavum aorticum; *ch.t.*, chordæ tendineæ; *l.au.*, left auricle; *o.p.v.*, opening of pulmonary vein; *o.pc.*, opening of dorsal division of synangium, by which blood passes from the cavum pulmocutaneum to the pulmocutaneous arch; *pc. a.*, pulmocutaneous arch; *r. au.*, right auricle; *s.au.*, sinu-auricular opening with valves; *sl.*, first row of semilunar valves; *sl'.*, semilunar valves of second row; *sl'.*1, the semilunar valve from which the spiral valve starts; the line points to a small portion of the valve which has been cut open; *sl'.2*, small semilunar valve at end of cavum pulmocutaneum; *sl'.3*, a small part of a large semilunar valve, of which the rest extends across that portion of the front wall of the truncus which has been removed; *sp.v.*, spiral valve; *sy.a.*, systemic arch; *tr.a.*, wall of truncus arteriosus; *tr'.*, one of the two bundles of arteries into which the truncus divides; *v.*, ventricle. (Redrawn from Borradaile.)

the liver and kidney substance, in addition to that received from their respective portal veins.

All the blood coming from the heart, and passing directly back to the heart, whether it flows through the portal, renal-portal, abdominal or other veins, is classified as the **systemic circulation.** This is to be distinguished from the **pulmonary circulation,** which deals with the blood which, having been returned by the veins to the heart, is now sent to the lungs to be purified and aerated. This blood leaves the heart **ventricle** through the pulmonary arteries and is returned to the heart **auricle** through the **pulmonary vein.**

It is interesting to note that, in the frog, a part of the already-used-blood (venous blood), which in the human being all goes to the lung through the pulmonary artery, passes through the **cutaneous artery,** a branch of the pulmonary, to the skin under the arm, where it is also purified by the oxygen in the water. It will be remembered that the frog needs **both air and water** for breathing purposes and breathes through both lungs and skin.

The frog's heart is composed of three compartments (Fig. 10), instead of four, as in the higher forms of animals. The blood, which has been purified in the lungs, flows into the **left auricle** through the pulmonary vein and is thus kept separate from the impure blood in the right auricle. But, as there is only **one ventricle,** and as blood is **always received by the auricles,** and **always expelled from a ventricle,** the impure blood from the right auricle, as well as the pure blood from the left auricle, is all emptied into one ventricle so that it is bound to intermingle. However, the blood from the right side is a little more impure than on the left, because the left side is **directly** connected with the left auricle and it is the left auricle which has the purest blood. The pure and impure blood are also kept partly separated by various irregular muscular partitions called **trabeculae** extending through the ventricle.

The action of the heart is as follows: The two auricles filled with blood contract at the same time, thus forcing the arterial blood from the left auricle and the venous blood from the right auricle into the ventricle. Here the two kinds of blood are kept from mixing by the trabeculae just mentioned. At the **systole** of the ventricle, some of the venous blood, which lies nearest the bulbus arteriosus, is first forced forward. This blood takes the most direct route through the wide and short pulmocutaneous arteries which are practically empty at the time. Some of the arterial blood is next forced out through the carotid arches to the head region, while the last blood to leave the ventricle is a mixture of the remaining arterial and venous blood, which is forced through the systematic arches to supply the general body system.

Blood usually looks red. This is due to the large red corpuscles (Gr. erythrocytes=erythros—red+cytos=cell). The redness itself is due to **haemoglobin,** a chemical substance contained within the corpuscles. There are also white corpuscles, called **leucocytes** (Gr. leukos=

white+cytos=cell), in the blood. These are often able to force themselves through the walls of the capillaries and then wander about through the tissues. In the liquid part of the blood there is still a third type of tiny bodies which are called **platelets.** Of these little is known.

Beside the arteries and veins there are also the **lymph vessels** in the skin, intestine, and other parts of the body which belong to the circulatory system. The liquid part of the blood in which the corpuscles float is known as **plasma.** When the blood passes into all parts of the body to nourish it, some of this plasma finds it way through the little arterial capillaries, bathing the **intercapillary** spaces. This plasma, which has left the blood vessel proper to bathe the body tissues, is called **lymph.** The lymph must be gathered again and made a part of the blood, so various little **lymph capillaries** drain the body and pour the lymph back into the veins. These lymphatic vessels are very delicate, and must be prepared in a special way to be seen. The little open spaces where lymph gathers and from which the lymphatics carry it to the veins, are known as a **lacunae.** These lacunae also connect with large cavities in the body.

The lymph vessels in the intestine have a special name, being called **lacteals** ( ). There are also lymphatic glands found

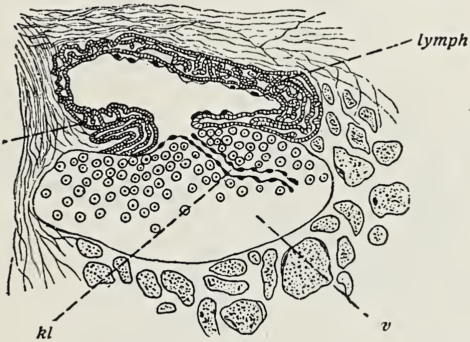


Fig. 11. Section Through a Lymph Heart. (After Weliky.)
kl—Tube-like valve at entrance of vein into the heart.
v—Vein.
lymph—Lymph-heart.

in connection with the lymph vessels. In the frog there are two pairs of **lymph hearts** (Figs. 11 and 347) whose **contraction** propels the lymph in its circulation.

With this in mind, we take up the principal divisions of the circulatory system.

PRINCIPAL DIVISIONS OF THE CIRCULATORY SYSTEM
THE HEART

There is a **true heart** consisting, however, of only **three cavities** (Fig. 10), two thin-walled **auricles,** ( ) one on the right and one on the left side, and a muscular **ventricle.** There is also a thick-walled tube called the **truncus arteriosus** ( ) arising from the **base** of the ventricle, and a thin-walled triangular sac, the **sinus venosus** ( ) from the dorsal side. The heart is the central pumping station of the entire circulatory system, which furthermore consists of all the **arteries, veins,** and **lymphatic structures** in the body. Arteries always carry blood **away** from the heart; veins, to the heart. The **fibers** of the heart muscle run in every direction, so that in **systole,** ( ) that is, when the heart **contracts,** its size is diminished, and the blood in the various cavities is forced out; then in **diastole,** ( ) when the heart again expands, the blood flows into it. The openings of both the auricles and ventricles are guarded by valves, little flaps of membrane which permit the blood to flow through the opening quite readily, but close up when the blood begins to flow backward, as it would be bound to do when the ventricle contracts, if the valves did not block the passage. The large truncus arteriosus (the proximal portion of which is called **bulbus arteriosus),** has two large branches, called

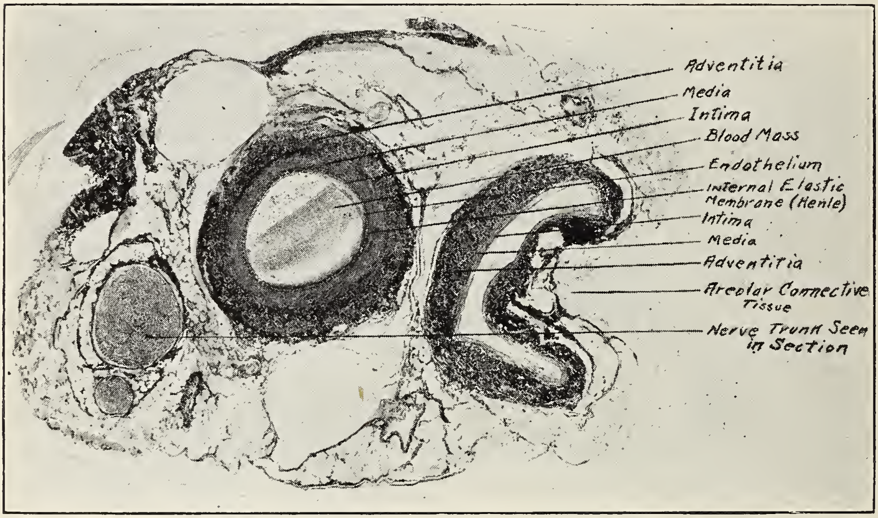


Fig. 12. Femoral Nerve, Artery and Vein of Puppy.

aortae ( ). The truncus receives the blood as it is forced out of the heart when that organ contracts. From here it is distributed to all parts of the body. The sinus venosus on the dorsal surface of the heart is the cavity into which the veins bring back the blood from all parts of the body. The sinus itself opens into the right auricle and thus receives all the blood which flows back to the heart from all parts of the body, **except the lungs.**

The blood from the lungs empties into the left auricle by two small veins, one from each lung.

THE ARTERIES

Blood vessels pass to every part of the body. We know they are everywhere because one cannot insert the point of the finest needle in any part of the body without piercing them, showing they are so close

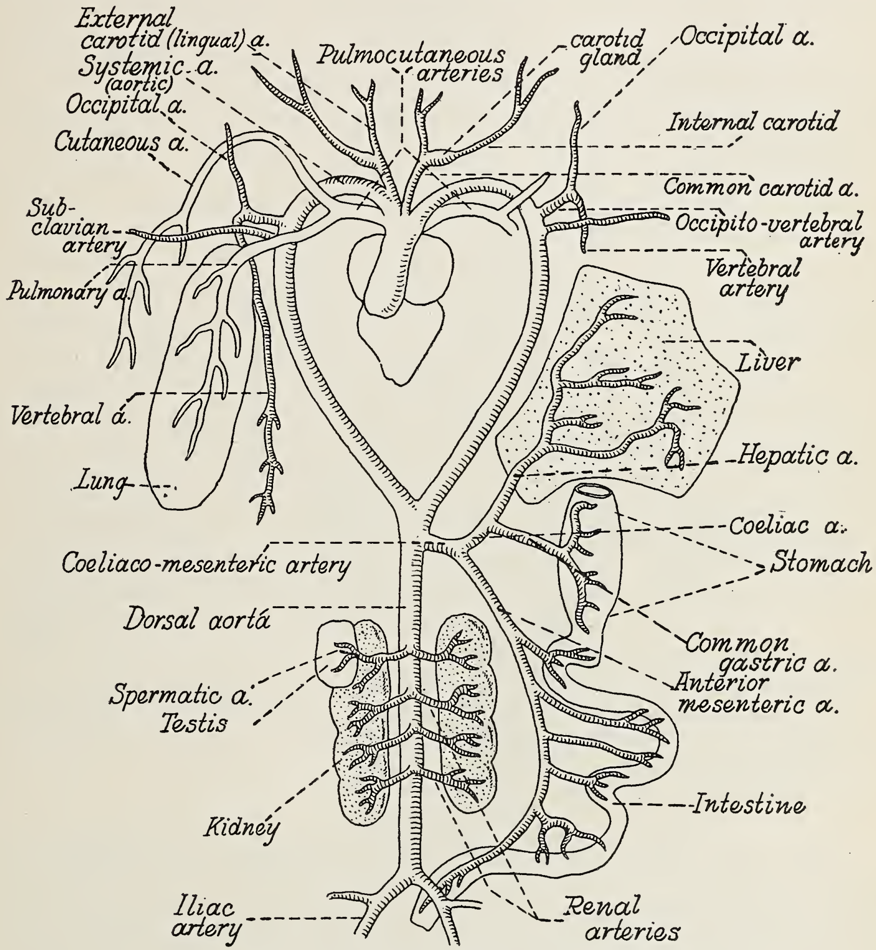


Fig. 13. The Arterial System of the Frog. (Redrawn from Meissner.)

together that one cannot get in between them. Arteries are always **relatively thicker-walled** and **more elastic** than veins (Fig. 12).

The principal divisions of the arterial system (Fig. 13) may be summarized as follows:

I. The **common carotid** ( ) divides into the **lingual** or **external carotid,** supplying the tongue and neighboring parts, and the **internal carotid** which gives off the **palatine** ( ) artery to the roof of the mouth, the **cerebral carotid** to the **brain** and the **ophthalmic artery** to the **eye.** There is a little swelling known as the **carotid gland** at the point where the common carotid branches.

II. The **pulmo-cutaneous** ( ) artery forms the **pulmonary** artery, passing to the lungs, and the **cutaneous** artery. The cutaneous in turn gives off the **auricularis** ( ) distributed to the lower body and neighboring parts, the **dorsalis** which supplies the skin of the back, and the **lateralis** which supplies the skin on the sides. Most of these branches also carry blood to the various respiratory organs, lungs, skin, and mouth.

III. The **systemic arches** pass outward, around the digestive canal, and then unite to form the **dorsal aorta.** Each systemic arch gives off an **occipito-vertebral artery** which divides; one branch, the **occipital,** ( ) supplies the jaws and nose; the other again divides to form the **vertebral** which supplies the spinal cord and muscles of the body wall; and the **subclavian** which is distributed to the shoulder, body-wall and arm. The dorsal aorta gives off the **coeliaco-mesenteric artery.** This divides, forming the **coeliac** which supplies the stomach, pancreas, and liver, and the **anterior mesenteric,** which is distributed under the intestine, the spleen, and the cloaca. Back of the **origin** of the coeliaco-mesenteric, the dorsal aorta gives off four to six **urinogenital arteries** which supply the kidneys, reproductive organs, and fat bodies. A small **posterior mesenteric artery** arises near the posterior end of the dorsal aorta passing into the rectum. In the female this artery also supplies the **uterus.** The dorsal finally divides into two **common iliac** ( ) **arteries** which are distributed into the ventral body-wall, the rectum, bladder, the anterior part of the thigh (here called **femoral artery),** and other parts of the hind limbs **(sciatic artery).**

All the arteries finally break up into a vast number of microscopic thin-walled vessels called capillaries (Lat. capillus=hair) by which every part of the body is reached.

THE VEINS

The veins (Fig. 14) return the blood to the heart by **draining** all parts through venous capillaries. The veins run in the opposite direction of the arteries and constantly become larger and larger. It will be noted here that the blood vessels form a **closed system** and the blood that leaves the heart returns to the heart without leaving the vessels. The blood from the lungs is collected by the pulmonary veins and poured into the **left** auricle while the rest of the venous blood is carried to the **sinus venosus** by three large trunks. There are two **anterior venae cavae** ( ) and one **posterior vena cava.** The anterior venae cavae receive blood from the **external jugulars** ( ) which collect the blood from the tongue, thyroid, and neighboring parts, as well as from the **innominates** which collect blood from the head by means of the **internal jugulars** and from the shoulder by means of the **subscapulars,** and the **subclavians** which collect blood from the fore limbs by means of the **brachial,** and from the side of the body and head by

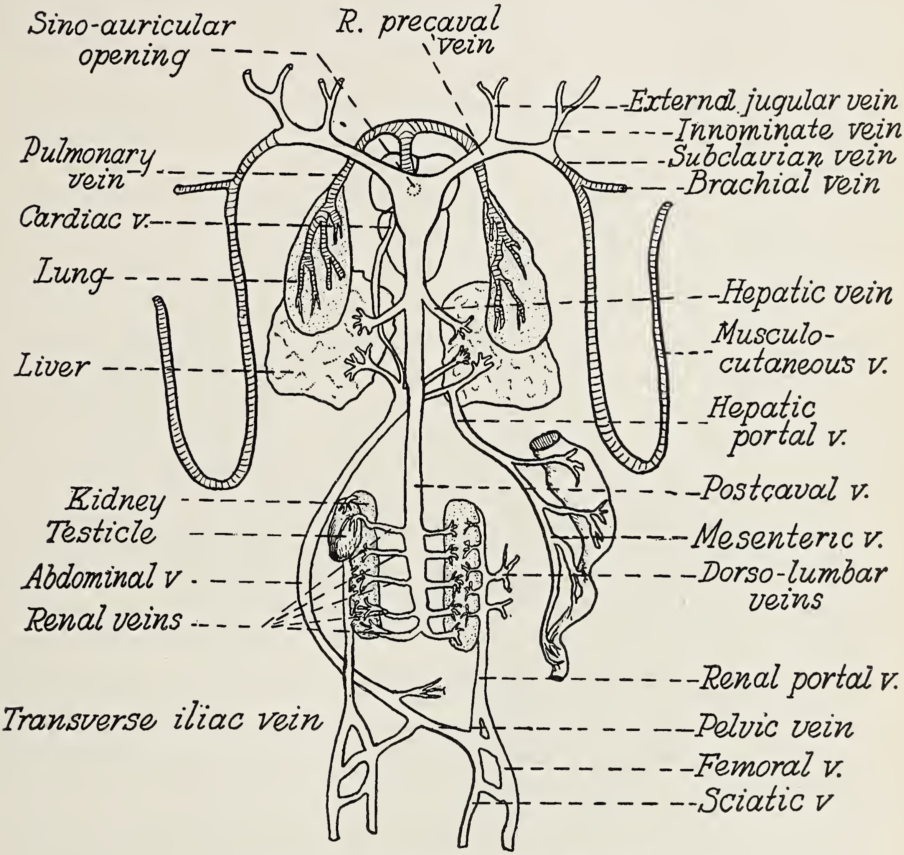


Fig. 14. The Venous System of the Frog.
(Modified from Meissner.)

Note that the blood returning to the heart from the posterior limbs must do one of two things: (1) It must pass through the kidney (renal portal system), or (2) it must pass, by way of the abdominal vein, through the liver (hepatic portal system). In either case, it enters the sinus venosus by way of the postcaval vein, and from there to the right auricle through the sinu-auricular opening.

means of the **musculocutaneous veins.** The posterior vena cava receives blood from the liver by means of two **hepatic veins,** from the kidneys by means of four to six pairs of **renal veins,** and from the reproductive organs by means of **spermatic or ovarian veins.**

The veins which carry blood to the kidneys constitute **the renal-portal** ( ) system. The renal-portal vein receives the blood from the hind legs by means of the **sciatic** and **femoral veins,** and the blood from the body-wall by means of the **dorso-lumbar vein.**

There is also an **hepatic-portal system** through which blood is brought to the liver. The femoral veins from the hind limbs divide, and their branches unite to form the **abdominal vein.** The abdominal vein also collects blood from the bladder, ventral body-wall, and heart. The **portal vein** carries blood into the liver from the stomach, intestine, spleen, and pancreas.

The general circulation is brought about by the sinus venosus contracting first to force the impure venous blood into the **right auricle.** Both auricles then contract, and the **oxygenated** ( ) **blood,** which was brought to the **left auricle** by the pulmonary veins, is forced into the **left part of the ventricle,** while the **impure blood** from the right auricle is forced into the **right side of the ventricle.** The ventricle then contracts, forcing out the impure blood. This impure blood first passes principally into the pulmocutaneous arteries and then to the lungs and skin. The oxygenated blood is pushed out later through the carotid and systemic arteries to the other parts of the body. The blood then passes through the various blood vessels which become smaller and smaller. These minute vessels are called capillaries. It is here that the food and the oxygen of the blood **bathe the tissues,** and **waste-products** are taken up.

The renal-portal system carries the blood from the legs and posterior portions of the body to the kidneys where **urea** and similar impurities are taken out. The hepatic-portal system carries **all** the blood **from the digestive tract** into the liver where bile and glycogen are formed. All blood brought to the lungs and skin is oxygenated and carried back to the heart.

The liquid in which the **blood corpuscles** float is called **blood-plasma** as long as it is contained **within the walls** of the blood vessel. When it leaves the blood vessel and bathes various parts of the intervening spaces, it is called **lymph; while,** if it should be taken **out of the body entirely,** it would be called **serum.**

The lymph spaces in the frog's body are very large and communicate with one another as well as with the veins. There are four so-called **lymph-hearts** (Figs. 11, 347); two near the third **vertebra,** and two near the end of the vertebral column. These **lymph-hearts** force the lymph into the **internal jugular** and **transverse iliac veins** by their pulsation. The lymph itself is colorless, and whatever corpuscles it may contain are likewise colorless.

RESPIRATION

As has been mentioned, breathing takes place through the **skin, both** in water and air, although the lungs are naturally the principal organs of respiration. The air is taken in through the external nares into the **olfactory** ( ) chamber, then through the internal or posterior nares into the mouth cavity. The valves then close; the floor of the mouth is raised, and the air is forced through the **larynx** ( ) into the lungs. The contraction of the body-wall forces the air back from the lungs into the mouth. It is interesting to note that the glottis closes, while the floor of the mouth alternately raises and lowers—thus drawing in and expelling air through the nares into the mouth cavity by what are called throat movements.

Fig. 15. Alveoli of Lungs.

The lungs themselves (Fig. 15) are formed of minute chambers called **alveoli,** ( ) the walls of which are filled with little blood capillaries. The larynx is strengthened by five **cartilages,** ( ) across which the vocal cords are stretched. The expulsion of air from the lungs across the free ends of the vocal cords produces the sound known as **croaking.** The **laryngeal muscles** regulate the **tension** of the cords which causes the particular pitch of the sound made.

Male frogs often have a pair of vocal sacs opening into the mouth cavity, serving as **resonators** ( ) and increasing the volume of the sound.

THE EXCRETORY SYSTEM

The food taken into the body is said to be **ingested.** The part of the food which is actually taken into the blood as nutriment, is said to be **digested,** and that part of the food, which passes directly through the body without becoming a part of it, is said to be **egested.** Every living cell ingests and must **assimilate** food in order to live; consequently, it must also get rid of that material which has already served a **nutrient purpose,** and this getting rid of a substance, which has been digested and has served a purpose, is called **excretion.** This word must not be confused with **secretion,** which means that a substance is given off from the cell or gland which is to be used again by some part of the body.

The waste matter eliminated from the body in the form of **carbon dioxide,** is thrown off through the organs of respiration, but the solid products have specialized organs for their removal. The skin serves as such an organ to a small extent. The frog does not use the skin in this way to the extent that human beings do, because **amphibia** do not possess **sweat glands.** The liver and the walls of the intestine are also excretory in character.

The most important organs for excretory purposes, however, are the kidneys; two oval, flattened, dark-red bodies lying **behind the peritoneum** in the dorsal portion of the body-cavity. It is well to know that the kidneys are about the only abdominal organs, even in the higher animal forms, which lie **between the dorsal peritoneum and body-wall.** The kidneys are abundantly supplied with blood vessels, though they, themselves, are composed of connective tissue. The fact that so many blood vessels run to the kidneys shows that these organs are decidedly important. Each kidney contains a great number of coiled tubes, called **uriniferous tubules,** each one of which begins in a **Malpighian** body near the ventral surface (Fig. 16). This body consists of a **knot of blood vessels,** called the **glomerulus,** and a surrounding membrane, known as **Bowman's capsule.** This capsule is really the thinned out and expanded end of a uriniferous tubule which has become pushed in by the glomerulus. All excretions are carried by the uriniferous tubules to a **collecting tubule,** and thence to the ureter. The ureter of each kidney passes **caudad** ( ) toward the cloaca, emptying therein, thence into the bladder, a large two-lobed sac. This latter organ

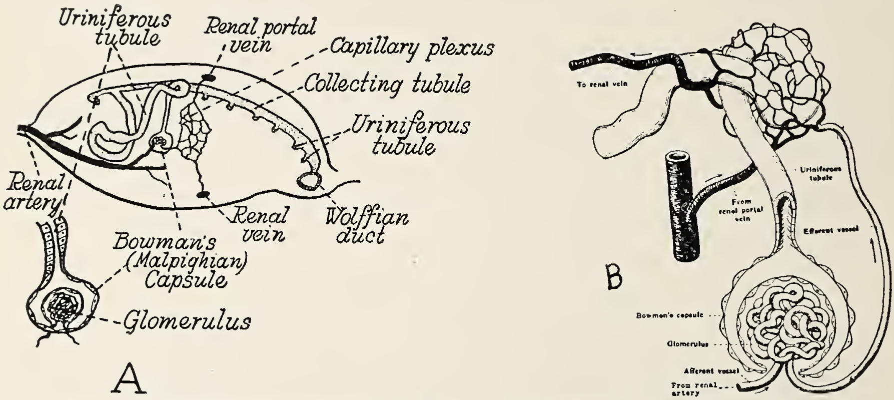


Fig. 16. A. Diagram Showing Formation of Renal Tubules and Bowman's Capsule. (After Borradaile.)
B. Diagram Showing Relation of Glomerulus and Renal Tubules to the Blood Vessels. (After Guyer.)

may be collapsed if empty; or, if filled with the urine secreted by the kidney it may be considerably distended. The ventral surface of the kidney has a great many **ciliated** ( ) **funnels,** called **nephrostomes** (Fig. 168), whose expanded ends open into the coelom. In the young frog these are connected with the **renal tubules,** while in the adult they open into branches of the **renal vein.** The **renal arteries** and the **renal-portal vein** carry the blood to the kidney, leaving again by the renal veins. The glomeruli are supplied only with arterial blood, but the renal tubules receive blood from the renal veins and to a slight extent from the renal arteries.

The **function** of the kidney is to **eliminate** the waste-matter from the blood. The excretion itself, known as urine, is composed of a large number of compounds in solution. Most of the **nitrogen** leaves the body in the form of **urea** $CO(NH_2)_2$, a white, crystalline compound, very soluble in water.

It is interesting to note that urea was the first **organic** chemical compound actually manufactured in the laboratory.

Urea represents the final product of the breaking down of the nitrogenous substances of the body. It has been shown that the formation of this substance takes place to a large extent in the liver from which it is given to the blood by a process of internal secretion. Beside urea, urine contains various salts in solution, such as chlorides, sulphates, phosphates of sodium, potassium, calcium, and magnesium, as well as other substances.

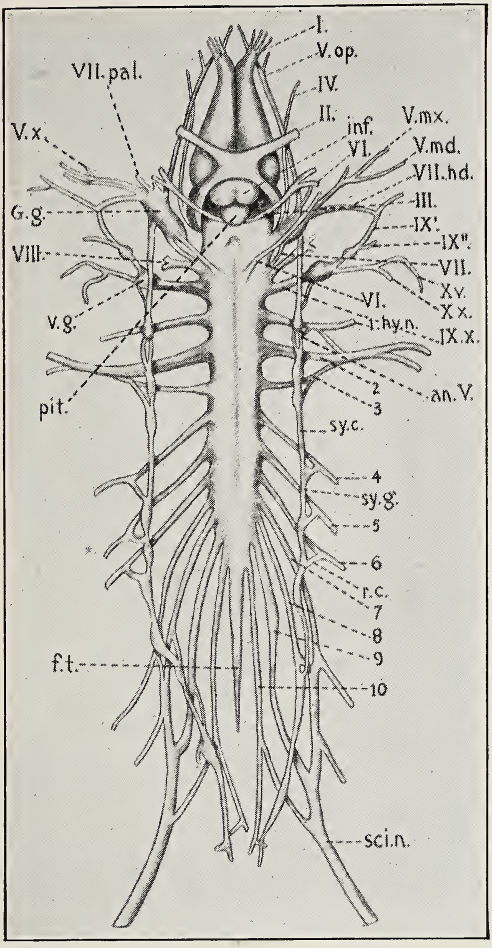


Fig. 17. The Central Nervous System and Principal Nerves of a Frog, Seen From Below.
I., Olfactory lobes; *II.*, Optic chiasma; *I.-X.*, cranial nerves; 1-10, spinal nerves; *V-md.*, *V.mx.*, *V.op.*, mandibular, maxillary, and opthalmic branches of fifth cranial nerve; *VI'*, sixth cranial nerve after leaving the Gasserian ganglion; *VII-hd.*, *VII-pal.*, hyoidean and palatine branches of seventh cranial nerve; *IX'.*, branch from ninth cranial nerve to seventh; *IX".*, main branch of ninth cranial nerve; *X.v.*, tenth cranial nerve passing to viscera; *V.x.*, a small twig from the undivided main branch of the fifth cranial nerve; *X-x*, a branch from the vagus to certain muscles; *an.V.*, annulus of Vieussens through which the subclavian artery passes; *f.t.*, filum terminale; *G.g.*, Gasserian ganglion; *hy.n.*, hypoglossal (first spinal) nerve; *inf.*, infundibulum; *pit.*, pituitary body; *r.c.*, ramus communicans; *sci.n.*, sciatic nerve; *sy.c.*, longitudinal commissure of sympathetic chain; *sy.g.*, sympathetic ganglion; *v.g.*, vagus ganglion. (Redrawn from Borradaile.)
Compare with Figures 472C, 478, 480, 483.

So far as we know at this time, practically all excreted substances of the kidney pass through the glomeruli. The exact function of the glomeruli is not known, though there are many theories regarding it.

The bladder arises as an **outpushing** of the ventral wall of the cloaca. It is regarded as homologous ( ) with the **allantois** (Fig. 363) of the embryo of higher vertebrates. It is very **distensible.** There are **circular muscles** at the mouth of the bladder which are able to contract and expand, the contraction closing the cloacal opening so as to make it possible for urine to collect in the bladder.

THE NERVOUS SYSTEM

One of the necessary conditions of life is what is commonly called **irritability,** which means that the organism can, when properly stimulated, perform certain movements. In the higher forms of animals a definite nervous system does this work and permits a **coördination** of activities in different parts of the body. For example: In order to leap when danger threatens, the frog must be able to send the necessary nervous impulses to both hind legs at one time, for if only one leg should get an impulse, the frog would fall over on one side instead of propelling its body for some distance ahead.

There is also another function performed by the nervous system. That is the **accumulation** of the **effects of experiences** which the animal in question has had, so that it may profit by the memory of these experiences in new situations. When this ability is highly developed, as in man, we speak of it as **reasoning** or **intelligence.** However, when the animal **only remembers,** let us say, a physical punishment for a given act, and by sheer association of the punishment and the act, ceases to perform the act which brought about the punishment, such an association is not known as intelligence, but as **association memory.**

Practically all parts of the body have nerves running to them. There are three closely associated divisions in the nervous system, (Fig. 17) known as:

1. The **central,** consisting of brain and spinal cord.
2. The **peripheral,** consisting of cerebral and spinal nerves, and
3. The **sympathetic,** supplying non-striated muscles.

THE CENTRAL NERVOUS SYSTEM

As in all vertebrates, the brain and spinal cord are on the **dorsal side** of the animal, being contained within a bony case known as the **skull** and **neural canal.** It will be noted that beginning at the anterior end, the brain consists of quite distinct parts, namely, the **olfactory lobes,** the **cerebral hemispheres,** the two large **optic lobes,** a well developed **mid brain,** a small **cerebellum,** and a broadening of the spinal cord itself, called the **medulla oblongata.** From the ventral surface, we may see in addition the crossing from one side to the other of the **optic nerves,** known as the **optic chiasma.**

A small process directly behind the optic chiasma, called the **infundibulum,** ( ) ends in another small body, the **pituitary body,** ( ) or **hypophysis** ( ).

On the dorsal side of the mid brain is found the **pineal gland,** ( ) or **epiphysis** ( ), already mentioned as a rudimentary organ which, in some forms of reptiles, forms a **dorsal median eye.** The **cerebrum** and **olfactory lobes** ( ) together constitute the **fore brain,** the **optic lobes form the mid brain,** the **cerebellum** and **medulla** form the **hind brain.**

It is not clear what functions each part of the frog's brain can perform. From various experiments, however, it is known that the frog loses the power of **spontaneous movement** if the mid brain and cerebral hemispheres are removed, while the spinal cord becomes very irritable if the optic lobes are cut away. No function has yet been definitely ascribed to the cerebellum and even when all of the brain, with the exception of the medulla, is removed, the animal breathes normally, snaps at and swallows food, leaps and swims regularly, and is able to right itself when thrown on its back. If the posterior portion of the medulla is removed, the frog dies.

THE SPINAL CORD

The spinal cord passes down through the bony **vertebral** or **spinal column.** It is short and somewhat flattened. There is an enlargement in the **brachial** region where the nerves pass off to the fore limbs, and one further back, where the large nerves originate, which supply the hind legs. The cord tapers to a narrow thread, called the **filum terminale,** which extends into the **urostyle.** There is a **median fissure** on both dorsal and ventral sides, while from the sides of the cord the roots of the spinal nerves are given off. The cord itself is surrounded by two membranes, an outer, the **dura mater,** and an inner, known as the **pia mater.** There is an H-shaped **central mass of gray matter** consisting of nerve cells, and an **outer mass** of **white matter** composed of nerve **fibers.**

There is a little opening through the center of the cord, called the **central canal.** The various cavities in the brain are a continuation and expansion of this central canal.

THE PERIPHERAL NERVOUS SYSTEM

The frog has **ten pairs** of **spinal nerves,** each arising by a dorsal and ventral **root** and springing from the **horns** of the gray matter of the cord (Fig. 470). The two roots unite to form a **trunk,** passing out between the **arches** of the vertebrae.

The **brachial,** or arm branches, are made up of the **second,** as well as branches from the **first** and **third pairs** of spinal nerves, and pass to the fore limbs and shoulder, while the **sciatics** arise from **plexuses,** composed of the **seventh, eighth,** and **ninth** spinal nerves, and run to the legs.

There are also **ten pairs** of **cranial nerves** which supply the **organs of special sense,** certain muscles, various organs of the head, the heart, lungs, and stomach. They are named as follows:[1]

1. The **olfactory** ( ) nerves, running from the olfactory lobes to the nasal cavities.

---

[1]There are two additional cranial nerves in the higher animals, the spinal accessory and hypoglossal, and medical students remember them by the following verse, the first letter of each word being the initial letter of the correspondingly numbered nerve:

I.	On	VII.	Finn
II.	Old	VIII.	And
III.	Olympus	IX.	German
IV.	Towering	X.	Picked
V.	Tops	XI.	Some
VI.	A	XII.	Hops

2. The **optic** nerves, running from the optic lobes, **crossing each other** to form the **optic chiasma** and passing to the eye on the opposite side of the head.

3. The **Oculomotor,** supplying the muscles of the eye.

4. The **Trochlearis** ( ), sometimes called the **patheticus,** supplying the muscles of the eye.

5. The **Trigeminus** ( ), or **trifacial,** a sensory nerve, supplying the sides of the head.

6. The **Abducens** ( ), supplying the muscles of the eye.

7. The **Facial,** chiefly motor in its action and supplying the sides of the head.

8. The **Auditory,** supplying the inner ear.

9. The **Glossopharyngeal** ( ), a sensory nerve, supplying the pharynx and tongue.

10. The **Pneumogastric** ( ), or **vagus,** supplying the larynx, heart, and stomach.

THE SYMPATHETIC SYSTEM

The main trunks of this system consist of a nervous strand on each side of the spinal column (Fig. 337). Throughout the abdominal cavity one may see the chain of minute **nerve ganglia, ten** in number, which are also connected with the spinal nerves. From these chains of ganglia tiny nerves are given off, supplying the intestine, the kidney, and other abdominal organs.

Although the sympathetic system is connected with the spinal nerves, it has entirely distinct and separate functions. **Microscopically,** one finds quantities of **neurones,** each with its little **cell-body, dendrites,** ( ) and **axon.** These are massed in the brain and cord, as well as in the ganglia outside of the cord. Some of them carry **impulses to** the **center** and some **away** from it. There are several branches where a vast intermingling of the sympathetic strands is seen, the principal ones being called the **coeliac,** ( ) or **solar plexus,** supplying the stomach, intestine, liver, pancreas, spleen, and sending fibers to the gonads and kidneys, and the **urogenital plexus,** supplying kidneys and gonads primarily.

THE SENSE ORGANS

If one marks a series of spaces on the **volar** ( ) surface of the fore arm of a human being about a millimeter square, and such person is then blindfolded, it will be found that, when a cold needle touches certain squares, he will feel a sensation of cold; whereas, if it touches certain other squares, he will feel a sensation of heat. From this experiment it is learned that a great many, if not all, nerves have a very special and definite work to perform.

Where a great mass of such specialized nerve endings is grouped in one place, it produces an organ of **special sense**, such as the **eye**, the **ear**, the **nose**, the **tongue**. All of these organs are groups of nerves whose endings are on the **surface** of some part of the body, and carry sensations **inward** to the **central nervous system**. These are called **sensory** nerves.

The nerves which **begin in the central nervous system** and go **outward** to some of the muscles, producing various movements of those muscles, are called **motor** nerves.

Both sensory and motor cells may unite in a **ganglion** and have both types of fibers run in the same sheath from there on; these are called **mixed** nerves.

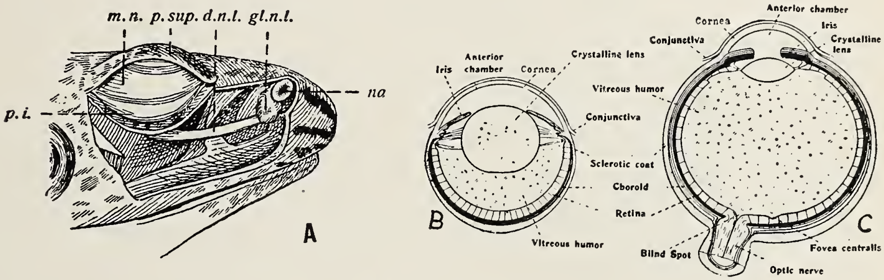


Fig. 18. The Eye.

A. Eye in position. *d.n.l.*, lachrimal duct leading from eye to interior of nose; *gl.n.l.*, lachrimal gland; *m.n.*, nictitating membrane; *n.a.*, nares; *p.i.*, lower eye-lid; *p.sup.*, upper eye-lid. (After Schimkewitsch.)
B. Diagrammatic section through the optical axis of the eye of the frog.
C. Diagrammatic horizontal section of the eye of man. (After Guyer.)

THE EYE

Probably the most important special sense organ is the eye (Fig. 18). Practically only one type of sensation is carried by the nerves of this special sense organ, and that is light perception. The eye of the frog is a large spherical organ similar to the eye of all of the higher animals. The walls of the organ are opaque with the exception of a transparent portion directly in the foreground, occupying about one-third of the eyeball, called the **cornea** (   ).

The darker portion of the eye acts as does the dark chamber of a camera. This chamber takes up about two-thirds of the posterior part of the eyeball and consists of three layers. Toward the exterior is found the **sclerotic** (   ) coat made up of **fibrous tissue** and **cartilage**. Then follows a thin **pigment-containing** coat, known as the

choroid, ( ) and in the inside of this a very thin layer, known as the **retina** ( ). It is the retina which is sensitive to light. Almost in the center, but a little to one side of the back chamber, the **optic nerve** enters, spreading out on the retina, so that it has a considerable area which may be affected by light. The **chamber** of the eye itself is divided in two parts by a transparent, spherical, **crystalline** lens which is held in position by several bands of fibers. The lens is partly covered anteriorly by an opaque membrane, in reality a continuation of the choroid, growing out of the wall of the chamber on all sides. This membrane is known as the **iris** ( ), and covers the entire outer portion of the lens with the exception of the center. This central uncovered portion is called the **pupil,** and it is through this that light enters. There are pigment cells in the iris which give the color to the eye.

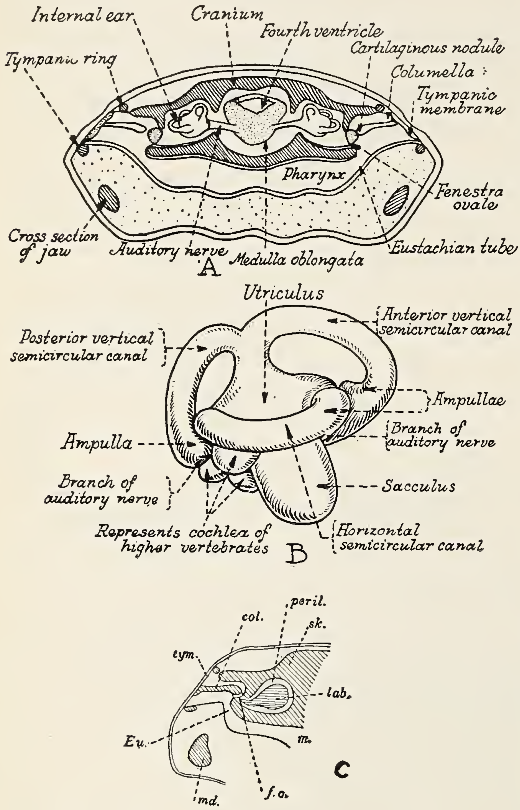


Fig. 19. The Ear.

A. Diagrammatic transverse section of the head of the toad showing arrangement of the parts of the ear. (After Guyer from Jammes.)
B. The labyrinth of the right ear of the frog, seen from the outer side.
C. A diagram of the ear of the frog. *col.*, Columella; *f.o.*, fenestra ovalis; *Eu.*, Eustachian tube; *lab.*, part of the membranous labyrinth, containing endolymph; *m.*, mouth; *md.*, mandible; *peril.*, perilymph; *sk.*, skull; *tym.*, tympanic membrane. (B and C, from Borradaile.)

Both of the eye-chambers are filled with a transparent liquid. That between the cornea and the lens is called the **aqueous humor,** ( ) and that back of the lens, which is quite thick, is called the **vitreous humor** ( ). The retina itself is quite complicated, being composed of thousands of **end organs** of sensory nerves, highly sensitive to the light focused upon it by the lens. There are six muscles attached to the eyeball by means of which it can be moved in practically any direction (Fig. 466).

THE EAR

As has already been noted, there are really no external ears on the frog, although there is a rounded, flat membrane covering the real ear (Fig. 19). Directly beneath this outer membrane there is another tougher one which is known as the **tympanic membrane** ( ). It extends over a shallow, cone-shaped cavity, called the **tympanum** or **ear-drum**, and connects with the mouth through the **Eustachian tube** ( ).

The **columella** ( ), a slender bar of bone and cartilage, extends across this, being attached to the membrane at one end and connected with the **inner ear** at the other. It is by this little bar that vibrations of the outer membrane are carried to the inner ear. This inner ear is the real organ of hearing and is made up of the **sensory end** of the **auditory nerve**. The auditory nerve lies embedded within the skull itself.

Several **semi-circular canals** are present which function as a balancing organ so that the animal can keep an upright position. These form an "organ of the **sense of equilibrium.**"

THE OLFACTORY ORGAN

Little is known regarding the effect that the sense of smell has in the life of a frog, but it is known that there are little **olfactory sacs** just within the bones into which the openings from the nostrils lead. The air enters these and then passes through the bones into the mouth by the **internal nares**. The ending of the olfactory nerve is in this little sac, where it is spread out to a considerable extent and where vapors of various kinds in the air may affect it.

THE TONGUE

The sense of taste probably resides in the tongue, though there are various small structures on the roof and floor of the mouth which may have similar functions.

Conclusions of this kind are based on observations of what the frog does when liquids of different taste are brought in contact with the structures mentioned.

The fact that the animal does react differently to different tastes is again accounted for by the fact that there are nerve endings in these probable taste organs.

TOUCH AND PRESSURE

These senses are located in those portions of the skin in various parts of the body where many sensory nerves terminate. Just as the experiment of the cold needle in contact with the arm of man demonstrates particular sensations for particular nerve endings in man, so we

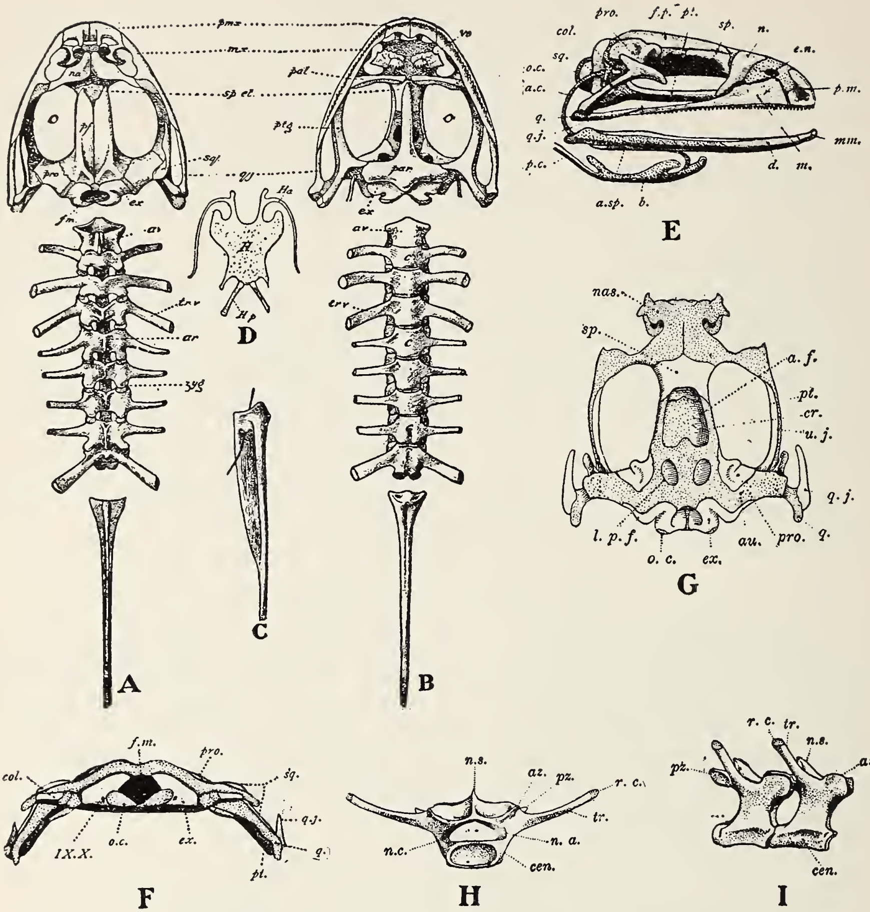


Fig. 20. The Axial Skeleton of the Frog.

A. The skull and vertebral column of frog viewed from dorsal surface.

B. The same from the ventral surface.

C. Lateral view of the urostyle; a bristle is passed through the foramen for the tenth spinal nerve.

D. The branchial skeleton of the frog: *O.*, orbital fossa; *pmx.*, premaxilla; *mx.*, maxilla; *q-j.*, quadrato-jugal; *na.*, nasal; *pf.*, parieto-frontal; *e.*, exoccipital; *fm.*, foramen magnum; *pro.*, prootic; *sq.*, squamosal; *sp.et.*, sphenethmoid; *par.*, parasphenoid; *pal.*, palatine; *vo.*, vomer; *ptg.*, pterygoid; *av.*, atlas; *c.*, centrum; *ar.*, neural arch; *zyg.*, zygapophysis; *trv.*, transverse process; *ur.*, urostyle; *H.*, body of hyoid; *Ha.*, anterior cornu; *H.p.*, posterior cornu of hyoid.

E. The skull of a frog, seen from the right side: *a.c.*, Anterior cornu of hyoid; *a.sp.*, angulo-splenial; *b.*, body of hyoid; *col.*, columella; *d.*, dentary; *e.n.*, external nasal opening; *f.p.*, fronto-parietal; *m.*, maxilla; *mm.*, mentomeckelian; *n.*, nasal; *o.c.*, occiptal condyle; *p.c.*, posterior cornu of hyoid; *p.m.*, premaxilla; *pro.*, prootic; *pt.*, pterygoid; *q.*, quadrate; *q.j.*, quadratojugal; *sp.*, sphenethmoid; *sq.*, squamosal.

F. The skull of a frog seen from behind: *col.*, Columella; *ex.*, exoccipital; *f.m.*, foramen magnum; *o.c.*, occipital condyle; *pro.*, prootic; *pt.*, pterygoid; *q.*, quadrate; *q.j.*, quadratojugal; *sq.*, squamosal; *IX.X.*, foramen for ninth and tenth cranial nerves.

G. The cartilaginous skull of a frog, seen from above after the removal of most of the bones: *a.f.*, Anterior fontanelle; *au.*, auditory capsule; *cr.*, cranium; *ex.*, exoccipital; *l.p.f.*, left posterior fontanelle; *nas.*, nasal capsule; *o.c.*, occipital condyle; *pro.*, prootic; *pt.*, pterygoid; *q.*, quadrate; *q.j.*, quadratojugal; *sp.*, sphenethmoid; *u.j.*, upper jaw bar.

suppose that different end-organs in the skin of the frog may also have definite functions.

THE SKELETON

The frog is possessed of an **endoskeleton** as is man. The bones and cartilages constituting this endoskeleton furnish a support which holds the muscles and organs of the body in position.

For convenience sake the skeleton is divided into two parts, the **axial** portion (Fig. 20), comprising skull and vertebral column, and the **appendicular** portion (Figs. 21, 22), consisting of the **pectoral** or shoulder, and **pelvic** or hip girdles, together with the bones of the limbs which these girdles support.

The frog's skeleton consists of about ninety **articulated** bones (united at the joints). The skull has the various bones comprising it so firmly fused that they appear as a single bone. Even the seemingly single bone of the fore arm will be found to consist of two bones which have fused together.

THE AXIAL SKELETON

This is divided into the **skull** [**cranium** ( ) and **visceral skeleton** ( )], and the **vertebral column.** The two divisions of the skull just mentioned are made up of the **brain case** together with the **auditory** ( ) and **olfactory capsules** ( ). These constitute the **cranium.** The jaws and **hyoid arch** ( ) together, form the **visceral skeleton.**

The inside of the cranium, where the brain is placed, is known as the **cranial cavity.** The skull itself is composed of thirty-two bones and cartilages fused together so as to appear almost a solid structure. The cranial bones form the **roof, walls,** and **floor** of the cranial cavity.

The **floor** is composed of the **basioccipital** ( ) and the **parasphenoid** ( ).

The **walls** consist of the **parietals** ( ), the **otic bones** ( ), and the **exoccipital** ( ).

The roof is made up of the **supraoccipital** ( ) and the **frontals.**

The **facial** bones, forming the face, consist of **nasals** ( ), the **premaxillas** ( ), and the **maxillas** ( ) above, and **vomers** ( ) below. The premaxillas and the maxillas, however, are a part of the visceral skeleton, comprising, together with a pair of **quadrangulars**, the upper jaws.

H and I. Vertebræ of a frog. H, fourth vertebra, seen from in front; I, sixth and seventh vertebræ from the right. *az.*, Prezygapophysis; *cen.*, centrum; *n.a.*, neural arch; *n.c.*, vertebral foramen; *n.s.*, neural spine; *pz.*, postzygapophysis; *r.c.*, cartilage at end of transverse process; *tr.*, transverse process.

(A, B, C and D from Bourne, after Ecker. E, F, G, H and I, after Borradaile.)

The maxilla and the premaxilla bear teeth. The lower jaw, or **mandibular arch** ( ), is made up of a pair of cartilaginous rods (Meckel's cartilages), enforced by a pair of **dentary bones** ( ) and a pair of **angulo-splenials** ( ). The jaws themselves are attached to the cranium by an apparatus consisting of **squamosals** ( ), **pterygoids** ( ) and **palatines** ( ), the whole often known as a **suspensory apparatus**, or a **suspensorium** ( ). These bones, though attached to the cranuim in the adult frog, are at first free from it, being in reality the upper parts of what are called **visceral arches**, which lie below the cranium. The **second arch** is called the **hyoid**, and is quite **rudimentary**, only a small part of it being left in the adult frog. In the higher animal forms, such as man, this is a well-developed V-shaped arch to which the tongue is attached; but in the frog it remains only as a flat plate, partly bone and partly cartilage, so loosely attached to the skull that it is quite easily, and one might add, usually, lost. It lies directly beneath the **larynx** ( ) in the frog, giving this support and rigidity, being connected with the skull by **ligaments** ( ) only.

In the young frog all parts of the skull are soft, but true bone forms as development goes on. A part of the skull forms originally as cartilage, a material that is harder than membrane but softer than bone. Mineral matter is deposited a little later in the cartilage, causing **ossification** ( ) or true manufacture of bone.

Bones, such as the occipitals, parietals, pterygoids, and the mandibles, formed from cartilage, are known as **cartilaginous bones**, the other ones being manufactured first as membranes. Here, too, mineral matter is laid down and the structures become hardened. Such bones as frontals, parietals, parasphenoids, squamosals, nasals, vomers, premaxillas, and maxilla, are of the latter kind and are called **membrane bones**. The projections at the posterior end of the skull, where it connects with the vertebral column, are called **occipital condyles** ( ); and the large opening directly between these, through which the spinal cord continues down through the bony canal of the spinal column, is called the **foramen magnum** ( ).

THE VERTEBRAL COLUMN

This consists of nine separate segments of bone (H and I, Fig. 20), each known as a vertebra ( ), and a long platelike posterior extension, the **urostyle** ( ). Each vertebra consists of a **centrum** and a neural arch ( ), the latter enclosing the **neural foramen.** On each side of all but the first vertebra there is found a **transverse process**, while all vertebrae possess a **dorsal spine** and a pair of smooth surfaces where each successive vertebra rests upon the next following. These **articulating processes** are called **zygapophyses** ( ). The little bones themselves are held together by ligaments and move on one another by means of the centrum and zygapophyses. This permits a firm **axial support,** while also allowing for the bending of the body. By having all the vertebrae, one immediately above the other, the neural opening is continuous, so that the spinal cord not only lies free, but the vertebrae themselves are thus prevented from bending sufficiently to damage the cord.

The surfaces of the centra unite by a **ball-and-socket joint.** Each of the first seven vertebrae possesses a ball on the posterior and a socket on the anterior surface. The eighth, however, is concave on both surfaces and the ninth is convex on both. It is important to know the difference in action which this entails. Although all nine vertebrae are much alike, they can easily be distinguished from one another. The first possesses no transverse process, while the centrum of the ninth has two convex posterior surfaces and very large transverse processes. It is from this last vertebra that the urostyle, the long slender bone, extends backward to the end of the body.

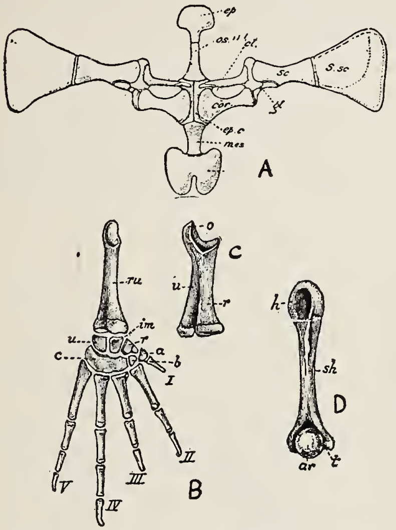


Fig. 21.
Pectoral Girdle, Arm, and Hand, of Frog.
A. The shoulder girdle of the frog; the scapula and suprascapula are turned outwards. *ep.,* episternum; *os,* omosternum; *ep.c.,* epicoracoids; *mes.,* mesosternum; *xi.,* xiphisternum; *s.sc.,* suprascapula; *sc.,* scapula; *gl.,* glenoid cavity; *cor.,* coracoid; *cl.,* clavicle.
B. Forearm and hand of right side, as seen from above; *ru.,* radio-ulna; *I—V.,* the five digits; *r.,* radiale; *im.,* intermedium; *u.,* ulnare; *a.,* first distal carpal bone; *b.,* second distal; *c.,* third distal.
C. Radio-ulna of right side: *o.,* olecranon; *r.,* radius; *u.,* ulna.
D. Humerus: *h.,* head; *sh.,* shaft; *ar.,* distal articular knob; *t.,* trochlea. (From Bourne, after Ecker.)

The urostyle is supposed to represent the tail found in allied animals, such as the **salamanders.** The spinal cord actually extends into the urostyle, but passes out almost immediately through two small openings on either side, as two rather tiny **filaments.**

There are no ribs in the frog, and the transverse processes end rather abruptly a very short distance from the centrum.

THE APPENDICULAR SKELETON

The shoulder, or **pectoral girdle,** ( ) (Fig. 21) serves as an attachment for the muscles which move the fore limbs, and also as a protection for the organs in the anterior portion of the trunk.

The girdle itself surrounds the body just back of the head, consisting of a paired **scapula** ( ), the dorsal part of which is made of cartilage, a **coracoid** ( ), a **precoracoid** or **epicoracoid**, and a **clavicle** ( ) fused together. At the meeting of coracoid and scapula there is a little smooth cavity where the arm joins the girdle called the **glenoid fossa** ( ). Where coracoid and clavicle meet at the mid line on the ventral side of the body, there are four bones. These four actually are a part of the axial skeleton, but are usually classified as a part of the appendicular as well. The most anterior one of the bones is called the **episternum**, the one between this and the clavicle is the **omosternum**, while the posterior one closest to the omosternum is the **mesosternum**, and the one projecting farthest backward is the **xiphisternum.**

The fore limbs are made up of a long bone, the **humerus** ( ), joining the pectoral girdle in the glenoid fossa at its **proximal end** ( ) and with the **radio-ulna** at the **distal end** ( ). This latter bone constitutes the skeleton of the fore arm and in reality consists of two bones, the radius and the ulna, fused together.

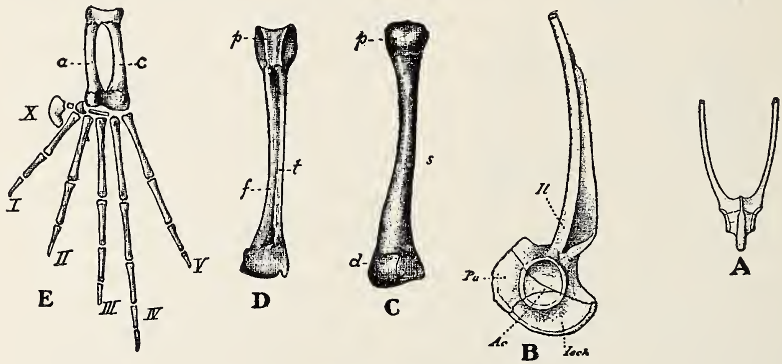


Fig. 22. The Pelvic Girdle and Leg.

A. Pelvic girdle complete.
B. One side of pelvic girdle: *Il.*, ilium; *Isch.*, ischium; *Pu.*, cartilaginous pubis; *Ac.*, acetabulum.
C. Femur of the frog: *p.*, proximal; *d.*, distal articulating surfaces; *s.*, shaft.
D. Tibio-fibula, seen from below: *p.*, proximal; *d.*, distal articulating surfaces; *t.*, tibial half of the bone separated by a groove from *f.*, the fibular half.
E. The right ankle and foot of the frog, seen from below: This figure is drawn to a larger scale than *A* and *B*. *a.*, astragalus; *c.*, calcaneum; *I—V.*, the five principal digits; *X.*, the minute accessory digit. (From Bourne after Ecker.)

The wrist possesses six bones, the **ulnare** ( ), **radiale**, ( ), **intermedium**, and three **carpals** ( ).

The hand has five proximal **metacarpal** ( ) **bones,** followed in **digits** ( ) II and III by two **phalanges** ( ), and in digits IV and V by three phalanges.

The **pollex,** ( ) or thumb, is rudimentary.

The **pelvic,** ( ) or **hip girdle,** (Fig. 22) supports the hind limbs, and consists of two sets of three parts each, the **ischium** ( ), **ilium** ( ), and the **pubis** ( ), the latter being cartilaginous, strongly united. The edge of the hip girdle is called the **crest.** The meeting of the two pubic bones forms a **symphysis** ( ). The anterior end of each bone is attached to one of the transverse processes of the arched vertebra. The little cup-shaped opening, where the three bones just mentioned meet, is called the **acetabulum** ( ). It is in this concavity that the head of the **femur** ( ), the long bone in the thigh, lies.

The hind limb consists of a **thigh** ( ) with the femur as its solitary bone. The leg proper, running from knee to ankle, is made up of the **tibia** ( ) and **fibula** ( ) fused together, called the **tibio-fibula,** or leg bone.

Note the ridges on these long bones for the attachment of muscles.

There are four **tarsal bones** ( ), the **astragalus** ( ), the **calcaneum** ( ), and two smaller ones.

The foot has five complete **digits** as well as an extra or **supernumerary** toe. Each digit has one proximal metatarsal bone, while beyond these there are a variable number of phalanges. The **hallux** ( ), corresponding to the great toe of man, is the smallest of the series. It has one metatarsal and two phalanges. On the inner side of the hallux is the **calcar** ( ), an extra toe. It may have one or two joints and a short metatarsal.

THE MUSCULAR SYSTEM

All movements in the body are produced through the **contraction** of some one or more muscles. The muscles in turn are **innervated** ( ) by one or more nerves. The muscle is usually attached by one or both ends to a bone, so that a good leverage is obtained. In some cases the attachment is direct. In others the muscle is attached by means of a **tendon.** A tendon is a band of tough, somewhat **inelastic, connective tissue** which is in reality the continuation of the muscle fascia after the muscle itself ends.

Contraction may be brought about by many causes, such as heat, pressure, electrical, or chemical **stimuli** ( ).

There are three distinct types of muscles (Fig. 23); each type has a more or less individual, cellular arrangement. These three types are known as **heart muscle, voluntary** or **striated** muscle, and **involuntary** or **nonstriated** muscle.

Striated muscle can be moved when the individual possessing it so desires. Such are the muscles of the arm and hand. Examples of nonstriated muscle may be found in the **blood vessels,** where the desire of the individual has little or nothing to do with the contraction and expansion of **circular** and **longitudinal muscles** contained within the walls of the blood vessels themselves.

The outer surface of all muscles is covered by a connective tissue membrane called **fascia** ( ), which is not very elastic. The fascia usually becomes thicker toward the end of the muscle, graduating in a dense, **fibrous band** called a **tendon** or, if this tendon is broad and flat, an **aponeurosis** ( ).

That part of the muscle most thoroughly attached—usually to a **relatively immovable part** and most frequently **toward the center of the body**—is called its **origin.** The **more movable** and **distal attachment** is known as its **insertion.**

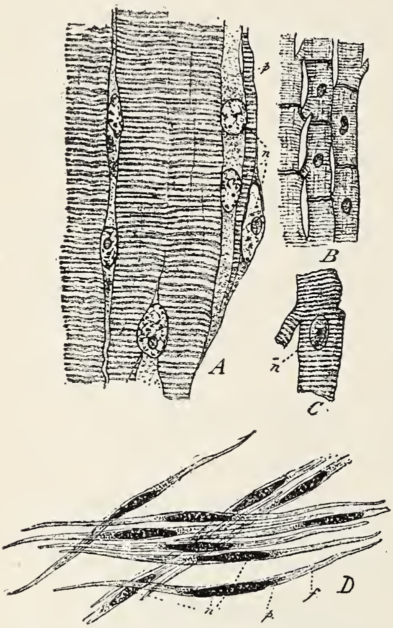


Fig. 23. Different Types of Muscle-Fibres.

A., embryonic striped muscle-fibre from the tail of a tadpole, showing the nuclei *nn.*, and the protoplasm *p.*, of the cœnocyte from which the fibres are developed. The fibres exhibit alternate dark and light bands, and in the center of each dark band is a light line, the line of Hensen.

B., cardiac muscle-fibre showing the short branched nucleated cells.

C., a single cell from cardiac muscle-fibre more highly magnified, showing the cross-striation and the nucleus *n.*

D., group of unstriped muscle-fibres from the bladder: *a.*, the nuclei; *p.*, the granular remains of the cell protoplasm; *f.*, the longitudinally striated contractile portion. (A and D, from Bourne. B and C from Schafer.)

The action of a muscle in contracting is to draw origin and insertion closer together.

Whenever a muscle moves any part of the body in its normal direction or as one may say, **with** the joint, such movement is called **flexion** ( ); against the joint, **extension** ( ). A muscle which pulls any limb or portion of a limb **away from** the **central axis of the body** is an **abductor** ( ), and one which draws the limbs or their appendages **toward the center of the body** is an **adductor** ( ). **Rotators** ( ) are those which cause the limb to **rotate** about its axis, such as those turning the femur at the hip; **levators** raise a part, such as the lower jaw; and **depressors** produce the opposite movement.

To **know** a muscle there are five points which must be remembered:

(1) Its Origin.

(2) Its Insertion.

(3) Its Relation to other structures.

(4) Its Innervation.

(5) Its Action.

The following list will convey a clear and accurate idea of what is essential in the study of the muscular system (Fig. 24). The relations of each muscle to surrounding structures can be obtained only by a dissection of the animal and a thorough study of the drawings.

A. MUSCLES OF THE TRUNK

1. Muscles of the lower or ventral side.

(a) Muscles of the abdomen.

e. g. **Rectus abdominis**, a wide band running along the abdomen, divided lengthwise down the middle by the connective tissue **linea alba** and transversely by **tendinous intersections.** Its origin is at the pubic sympysis and its insertion at the sternum.

Obliquus externus, a broad sheet at each side of the body, arising from an **aponeurosis** known as the **dorsal fascia** which covers the muscles of the back, and inserted into the linea alba above the rectus abdominis.

Obliquus internus and **transversus**, muscular sheets below the external oblique.

By their contraction, all these muscles lessen the size of the body cavity and compress the organs within it.

Innervation: All of these muscles are innervated by twigs from IV, V, VI and VII spinal nerves.

(b) **Muscles of the Breast Region.**

e. g. **Pectoralis**, large and fan-shaped, inserted into the deltoid ridge of the humerus and consisting of a **sternal portion** which arises from the pectoral girdle, and an **abdominal portion** which arises from the aponeurosis at the side of the rectus abdominis.

It draws down the arm.

Innervation: Twig from II spinal nerve.

Coraco-radialis, arising from the coracoid and inserted into the upper end of the radius. It bends the arm.

Innervation: Twig from II spinal nerve.

2. Muscles of the Back.

(a) **Muscle inserted into the lower jaw.**

Depressor mandibulae, triangular, arising from the suprascapula and inserted into the angle of the lower jaw, which it draws downwards and backwards, thus opening the mouth.

(b) **Muscles inserted on the fore-limb.**

e. g. **Latissimus dorsi** ( ) triangular, arising from the dorsal fascia and inserted into the deltoid ridge. It draws back the arm.

Infraspinatus, in front of and similar to the latissimus dorsi. It raises the arm.

Innervation: Twig from II spinal nerve.

(c) **Muscles inserted into the shoulder girdle.**

e. g. **Levatur anguli scapulae,** arising from the skull and inserted into the under side of the suprascapula, which it draws forward. Innervation: Twig from I spinal nerve.

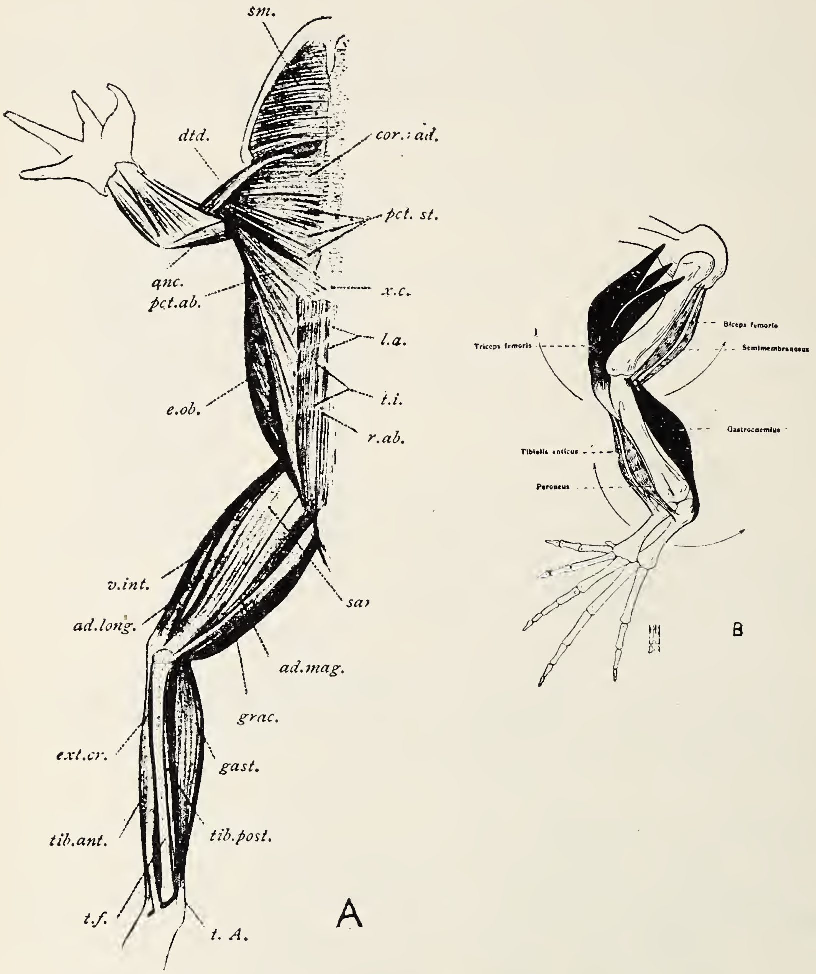


Fig. 24. A—A Ventral View of the Muscular System of a Frog.

ad.long., Adductor longus; *ad.mag.*, adductor magnus; *anc.*, anconæus; *cor.rad.*, coraco-radialis; *dtd.*, deltoid; *e.ob.*, external oblique; *e.cr.*, extensor cruris;*gast.*, gastrocnemius; *grac.*, gracilis; *l.a.*, linea alba; *pct.ab.*, abdominal part of the pectoral muscle; *pot.st.*, sternal part of the same; *r.ab.*, rectus abdominis; *sar.*, sartorius; *sm.*, mylohyoid; *t.i.*, tendinous intersections; *t.A.*, tendo Achillis *t.f.*, tibiofibula; *tib-ant.*, tibialis anterior; *tib.post.*, tibialis posterior; *v.int.*, vastus internus; *x.c.*, xiphoid cartilage. (After Borradaile.)

B. Dissection of special muscles of the left hind leg of the toad (redrawn from Jammes). Muscles shaded in black are *extensors*, in gray, *flexors*.

Serratus, arising from the little knobs on the transverse processes of the vertebrae which represent the ribs, and inserted into the under side of the suprascapula, which it draws backwards, outwards, or inwards, according to the division which is contracted.

(d) **Muscles inserted into the hind-limb.**

e. g. **Gluteus** (iliacus externus, or gluteus medius), arising from the ilium and inserted into the head of the femur, which it rotates inwards.

(e) **Muscles inserted into the hip girdle.**

e. g. **Coccygeo-iliacus**, arising from the urostyle and inserted into the ilium, which it holds firm as a fulcrum for the movements of the hind-limb.

(f) **Muscles of the Backbone.**

e. g. **Longissimus dorsi**, a band running the whole length of the back, divided by tendinous intersections, which are attached to the transverse processes, and inserted in front into the skull. It straightens the back.

Innervation: Twig from I spinal nerve.

B. MUSCLES OF THE HEAD

1. Muscles underneath the Head.

e. g. **Sternohyoid**, from hyoid to pectoral girdle.
Geniohyoid, from hyoid to chin.
Hyoglossus, from hyoid to tongue.
Petrohyoid, from hyoid to auditory capsule.
Mylohyoid, submandibular, or submaxillaris ( ), a sheet of muscle running from side to side of the lower jaw. These muscles alter the position of the floor of the mouth.

Innervation: Twigs from I spinal nerve.

2. Muscles of the Lower Jaw.

e. g. **Temporalis** and **masseter** ( ), arising from the skull and inserted into the lower jaw, which they raise.

Innervation: Mandibular branch of the V cranial nerve.

3. Muscles of the Eyeball (Fig. 466).

Rectus superior, r. inferior, r. externus, r. internus, arising from the skull in the hind part of the orbit and inserted into the eyeball.

Innervation: All but the rectus externus from the III cranial nerve. The r. externus by the VI cranial nerve.

Obliquus superior and **o. inferior**, arising from the skull in the front part of the orbit and inserted into the eyeball.

Innervation: Obliquus superior by the IV cranial nerve and o. inferior by the III cranial nerve.

C. MUSCLES OF THE FORE-LIMB

1. Muscles of the Upper Arm.

e. g. **Deltoideus,** arising from the scapula and inserted into the humerus. It raises the arm.

2. Muscles of the Fore-Arm.

Triceps brachii or **anconaeus** ( ), arising from the scapula and humerus, and inserted into the upper end of the ulna. It straightens the arm.

There is no **Biceps** muscle in the arm of the frog.

3. The **muscles** of the **Wrist and Fingers** are numerous and complicated.

Innervation: Branches and twigs of II spinal or brachial nerves innervate all arm and finger muscles.

D. MUSCLES OF THE HIND-LIMB

(1) **Superficial muscles of the Thigh on the Preaxial** (apparent ventral[1] **Surface.**

1. **Sartorius** ( ), a long, narrow band arising from the lower end of the ilium, lying obliquely upon the abductor magnus, and inserted into the tibia on its inner side near the end. It bends the knee.

2. **Adductor magnus,** a large muscle arising from the pubis and ischium, lying along the inner border of the sartorius and inserted into the femur near its lower end. It draws the thigh toward the body.

3. **Adductor longus,** a long, narrow muscle lying along the outer side of the adductor magnus, and often completely hidden by the sartorius; it arises from the iliac symphysis beneath the sartorius, and unites a little way beyond the middle of the thigh with the adductor magnus. It adducts the thigh and draws it ventrally.

4. **Gracilis major** ( ), or **rectus internus major,** is a large muscle arising from the ischium, lying along the inner side of the adductor magnus, and inserted into the inner-side of the head of the tibia. It bends the knee.

5. **Gracilis minor,** or **rectus internus minor,** is a narrow flat band of muscle running along the inner, or flexor margin of the thigh. It rises from a tendinous expansion connected with the ischial symphysis, and

---

[1]The femur of the frog rotates away from the midline more than does the femur of man. Consequently the true outer border of the frog's thigh is equivalent to the inner border of man's. In other words the preaxial surface of the frog's thigh is equivalent to the inner surface of man's.

is inserted into the inner side of the tibia, just below its head. Its action is the same as for gracilis major.

Innervation: Branches and twigs from the sciatic nerve and plexus.

(2) **Superficial muscles of the Extensor Surface of the Thigh.**

1. **Triceps extensor femoris,** or **cruris,** a very large muscle inserted into the front of the tibia just below the head of the latter, but arising from the pelvic girdle as three separate muscles, the **rectus anticus femoris** ( ), **vastus externus** ( ), and **vastus internus, or crureus** ( ). All these lie **on the front of the thigh,** and their action is to straighten the knee.

Innervation: Branches and twigs from the sciatic nerve and plexus.

(3) **Superficial muscles of the Postaxial Surface (apparent dorsal) of the Thigh.**

1. The **gluteus** (iliacus externus), already mentioned, lies in the thigh between the rectus anticus femoris and the vastus externus. It draws the thigh forward.

2. The **biceps** (ileo-fibularis) is a long slender muscle which arises from the crest of the ilium just above the acetabulum. It lies in the thigh along the inner border of the vastus externus, and is inserted by a flattened tendinous expansion into the distal end of the femur and the head of the tibia-fibula. It draws the thigh dorsally and flexes the leg.

3. The **semimembranosus** is a stout muscle lying along the inner side of the biceps, between it and the rectus internus minor. It arises from the dorsal angle of the ischial symphysis just beneath the cloacal opening, and is inserted into the back of the head of the tibia. It is divided about its middle by an oblique tendinous intersection. It adducts the thigh and flexes or extends the leg according to whether the leg is in a flexed or extended position.

4. The **pyriformis** is a slender muscle which arises from the tip of the urostyle, passes backward and outward between the biceps and the semimembranosus, and is inserted into the femur at the junction of its proximal and middle thirds. It pulls the urostyle to one side and draws the femur dorsally.

Innervation: Branches and twigs from sciatic nerve and plexus.

(4) **Deep muscles of the Thigh.**

1. The **semitendinosus** is a long thin muscle which arises by two heads; an **anterior one** from the ischium close to the ventral angle of the ischial symphysis and the acetabulum; and a **posterior one** from

the ischial symphysis. The anterior head passes through a slit in the adductor magnus and unites with the posterior head in the distal third of the thigh. The tendon of insertion is long and thin, and joins that of the rectus internus minor to be inserted into the tibia just below its head. It adducts the thigh and flexes the leg.

2. The **adductor brevis** is a short, wide muscle, lying beneath the upper end of the adductor magnus. It arises from the pubic and ischial symphyses, and is inserted into the preaxial surface of the proximal half of the femur.

3. The **pectineus** ( ) is a rather small muscle, lying along the outer (extensor) side of the adductor brevis. It arises from the anterior half of the pubic symphysis in front of the adductor brevis, and is inserted like it into the proximal half of the femur.

4. The **ilio-psoas** (iliacus internus) arises by a wide origin from the inner surface of the acetabular portion of the ilium. It turns round the anterior border of the ilium, and crosses in front of the hip-joint, where, for a short part of its course, it is superficial between the heads of the vastus internus and of the rectus anticus femoris. It then passes down the thigh beneath these muscles, and is inserted into the back of the proximal half of the femur. It draws the thigh forward.

5. The **quadratus femoris** is a small muscle on the back of the upper part of the thigh; it arises from the ilium above the acetabulum, and from the base of the iliac crest; it lies beneath the pyriformis and behind the biceps, and is inserted into the inner surface of the proximal third of the femur between the pyriformis and the ilio-psoas.

6. The **obturator** is a deeply situated muscle which arises from the whole length of the ischial symphysis and the adjacent parts of the iliac and pubic symphyses, and is inserted into the head of the femur close to the gluteus.

Innervation: Branches and twigs from sciatic nerve and plexus.

5. **Muscles of the Leg or Shank.**

e. g. (1) **Peroneus,** a long muscle which arises from the end of the femur, lies along the side of the tibio-fibula, and is inserted into the end of the tibia and the **calcaneum** ( ). It extends the leg and the foot and flexes the foot.

Innervation: Peroneus nerve.

(2) **Gastrocnemius** ( ), a large, spindle-shaped muscle which forms the "calf." It arises from the hind side of the end of the femur and tapers into the long **tendo Achillis,** which passes under the ankle joint and ends in the sole of the foot. It straightens the foot on the shank.

Innervation: Tibialis nerve.

(3) **Tibialis anticus**, arising from the front of the femur by a long tendon, lies in front of the shank and divides into two bellies, which are respectively inserted into the **astragalus** and **calcaneus**. It bends the foot on the shank.

Innervation: Peroneus nerve.

(4) **Tibialis posticus** arises from the whole length of the flexor surface of the tibia. It ends in a tendon which passes round the inner **malleolus** ( ), lies in a groove in the lower end of the tibia and is inserted into the dorsal surface of the **astragalus**. It extends the foot when flexed, and flexes the foot when extended.

Innervation: Tibialis nerve.

(5) **Extensor cruris** lies along the preaxial side of the tibialis anticus partly covered by this and partly by the strong fascia of the leg. It arises by a long tendon from the preaxial **condyle** of the femur, runs in a groove in the upper end of the tibia, and is inserted into the extensor surface of the tibia along nearly its whole length. It extends the foot.

Innervation: Tibialis nerve.

6. **Muscles of the Foot.**

These, just as the muscles of the wrist and hand are many and complicated, but the student should know at least the general location of the following:

Aponeurosis plantaris.

The flattened and broadened continuation of the tendon of the gastrocnemius muscle passing over the heel and spreading out on the sole of the foot in a sort of triangle with the base toward the toes. Where the aponeurosis crosses the heel it is known as the **tendon of Achilles.**

Flexor digitorum I, II, III, IV, V.

Each digit usually has a flexor, extensor, abductor, and adductor bearing the number of the toe to which it is attached, the great toe being **I.**

There are also small **interosseus** muscles between the various tarsal bones.

For a detailed account of all muscles of the frog see: Ecker's "The Anatomy of the Frog." (Oxford University Press.)

REPRODUCTIVE ORGANS

The sexes are separate in the frog. The male has a rather thick pad on the underside of its thumb, larger in the spring, at the breeding season, than at any other time of the year. The two rounded or oval **spermaries** (A, Fig. 25), of a light yellow color, are found at the upper end of the kidneys, while branching masses of a yellow shade are usually attached to them. The **sperm**, the **male gamete** ( ), is produced in the spermaries, being carried through slender **ducts**, the **vasa efferentia**, through the kidney to empty into the **ureters.** It will be observed, therefore, that in the male frog the ureters serve **both** as **an exit** for the **excretion** of the kidneys and for the **secretions** of the spermaries. In some species of frogs, the ureters are slightly enlarged to form a small sac just where they enter the cloaca. Such sacs are

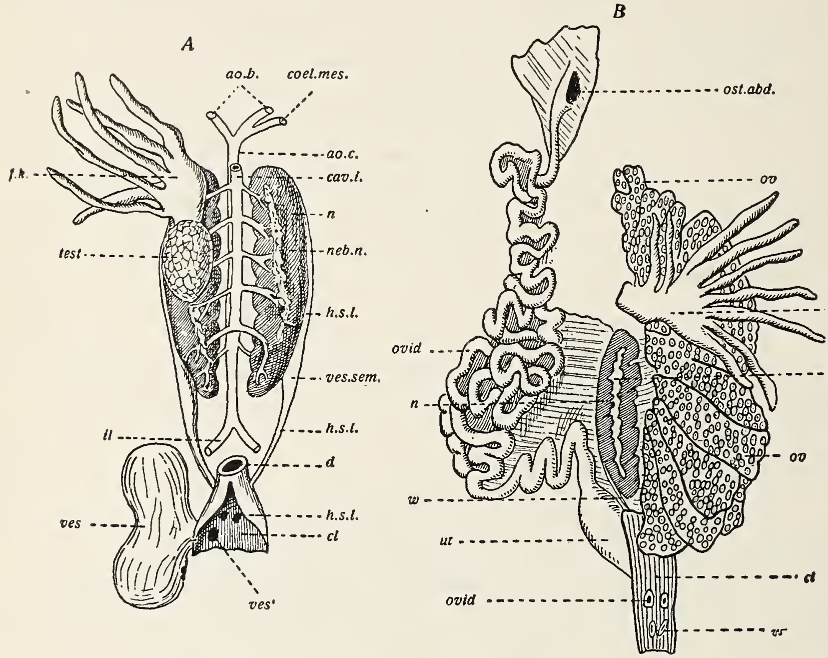


Fig. 25. The Urogenital Organs of the Frog. A, Male; B, Female.

ao.b., systemic arteries; *ao.c.*, main aortic trunk; *cav.i.*, vena cava inferior; *cl.*, cloaca (dissected from the ventral side); *coel,mes.*, coeliaco mesenteric artery; *d.*, large intestine; *f.k.*, fat bodies; *h.s.l.*, urogenital duct; *h.s.l.'*, entrance of urogenital duct into cloaca; *il.*, iliac artery; *n.*, kidney; *neb.n.*, adrenal bodies; *ost.abd.*, funnel-shaped opening of oviduct; *ov.*, ovary; *ovid.*, oviduct; *ovid.'*, entrance of oviduct into cloaca; *test.*, testes; *ut.*, uterus; *ves.*, urinary bladder; *ves.'*, opening of bladder into cloaca; *ves.sem.*, seminal vesicle; *w.*, Wolfian duct; *w.'*, opening of Wolfian ducts. (After W. Meissner.)

known as **seminal vesicles.** The sperm are held there until ready to be discharged.

If the body of a female (B, Fig. 25) be opened in the breeding season the **ovaries** will be found filled with **eggs** which seem to fill almost the entire body-cavity. The ovaries, the female **gonads** ( ), are placed in a position corresponding to the spermaries in the male. If it is not the breeding season, the ovaries are rather small, slightly folded and leaf-life, not very much larger than the spermaries, but of a different shape. The eggs break out of the ovary into the body-cavity and make their way into the **coiled oviduct** through a small opening, passing down into the thin-walled distensible **uterus** ( ). The oviducts themselves are not directly connected with the ovaries, but lie coiled next to the kidneys, the anterior end being a funnel-shaped opening. The tube itself passes caudad beside the kidney to open into the cloaca. The uterus is the rather large thin-walled chamber at its termination, in which the eggs are stored after passing through the oviducts until the final egg laying. The oviducts themselves, like the ovaries, vary in size at different seasons of the year.

The **gelatinous substance** covering the eggs is secreted by little glands in the oviducts, called **nidamental glands** (Lat. nidus=a nest). It is to be observed that the sexual organs and kidneys lie close together and have a common opening, and in the male the same duct, namely, the ureter, serves for an exit of both sperm and urine. A similar close relation is found in nearly all other vertebrates, and when the study of **embryology** is taken up it will be found that the ducts and kidneys were originally derived from the same region of the embryo. It is, therefore, common to speak of the excretory and reproductive system together as the **urogenital system.**

THE FAT BODIES

Directly in front of the gonads, we find a yellow organ with many finger-like processes known as a fat body. It has a broader and closer attachment to the anterior end of the male gonad than it has to the female ovary. It is supposed to serve as a storehouse of nutriment, for it varies in size and shape at different seasons of the year. Nearly all the fat disappears from the cells in spring while as soon as the feeding period begins the fat increases.

References:

Ecker, "The Anatomy of the Frog."
Holmes, "The Frog."
Parker & Haswell, "Textbook of Zoölogy."
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CHAPTER V

THE CELL

IT will be observed later in the study of the histology of the frog that the different types of cells vary in size and shape. Some are round, others more or less cuboidal, still others cylindrical, etc. As there are animals possessed of but a single cell which can nevertheless perform all acts necessary to a complete organism and, consequently, can lead an independent existence, **the cell** is called the **biological unit,** and facts in the biological world are not considered explained until they have been reduced to **terms of cell units.**

Not a living thing, plant or animal comes into existence which does not start life as a single cell. It is, therefore, an **axiom** ( ) of science that there can be no living cell **unless it sprang from a previous cell.** Therefore, an egg, regardless of whether it be the small egg of a frog or so large a one as that of the ostrich, is only a single cell. In fact, in the hen's egg usually used in the laboratory for experimentation, the yolk represents the food for the offspring, the egg **proper** being that little portion, about the size of a dime, which always floats on the top of the yolk, regardless of the position of the egg.

The following drawing (Fig. 26) is that of an **ideal cell.** This means that **everything** which the student will ever find **in any cell,** plant or animal, **is contained in this drawing.** One must remember, however, that search may be made from now until the end of time and **no one cell** may ever be found with all the parts shown in this ideal cell.

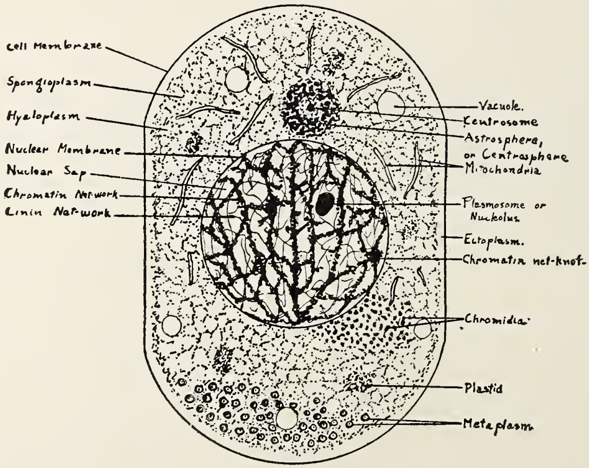


Fig. 26. An Ideal Cell.

The entire substance surrounded by the **cell wall** is called **protoplasm.** This is a jelly-like, or **viscous, material** something like the white of an egg. Probably most cells have a definite wall, though many animal cells do not. On the inside of this cell wall there is a network, or **reticulum,** in which are found little **foreign bodies, plastids,** and open spaces called **vacuoles.** The network itself is called **spongioplasm,** because it somewhat resembles a sponge. The liquid protoplasm on the inside of this network is called **hyaloplasm** ( ). On the inside of the cell there is a seemingly smaller cell, called the **nucleus.** This nucleus is considered the most important part of the cell. A cell may have one nucleus, or it may have many. There is a **nuclear** wall just as there is a cell wall, and on the inside of the nucleus there is also a network or reticulum.

When a cell has been **chemically stained** with various substances, it is found that **a portion of the network in the nucleus takes the stain, while a portion does not,** showing that this nuclear network is composed of at least two different substances. **The part which takes the stain is called the chromatin ( ) network,** and the part **which does not take the stain is called the linin ( ) network.** This nuclear network which takes the stain usually stands out quite distinctly from the rest of the cell, making it appear at first glance as though the entire nucleus had taken a great quantity of stain to itself.

The substance lying within the network of the nucleus is called **nucleoplasm.** It may happen that some cells do not have a definitely outlined nucleus with a nuclear wall, but nevertheless these cells have **nuclear material** scattered throughout the cell itself in the form of **granules**; such granules are known as **distributed nuclei.** In the red blood corpuscles of the human being there are no nuclei in the adult form, although such red cells **are nucleated** when they originally begin growing.

On the inside of the nucleus there is in turn a **smaller nucleus** which is called the **nucleolus** ( ).

At certain places in the nucleus where the various fibers of network cross each other, there may be little knots, called **net-knots,** but these must not be confused with the nucleoli. The chromatin itself appears in a granular form, and the granules are called **chromomeres** ( ).

There may even be two nucleoli in one nucleus. These stain quite readily also, but appear somewhat different from the chromatin after such staining. Exactly what the nucleolus does, biologists do not know. **It disappears during the time the cell divides** and consequently has been thought to serve the purpose of holding something in reserve for the **division process.**

All of the material **within the cell walls,** but **outside the nucleus,** is known as **cytoplasm**, to distinguish it from the **nuclear material** within the **nuclear wall** or membrane.

Just **outside of the nucleus** and **within the cytoplasm**, there is usually found a tiny circle with a dot in the center. The dot itself is called the **centrosome** ( ) and the circle about it the **attraction sphere**, or **centrosphere**.

There are little perforations through the nuclear wall so that there is a direct connection between nucleoplasm and cytoplasm.

CELL INCLUSIONS AND CELL PRODUCTS

Bodies of a solid nature, not protoplasmic, are common to many cells. These are **pigments, oil, fat, crystals, glycogen, starch, chlorophyl, etc.**, and are commonly spoken of as **cell inclusions**, though as a matter of fact only foreign substances such as bacteria, etc., should be called inclusions. Starch and chlorophyl are found almost exclusively in plant cells. By these inclusions the shape of the cell is often changed, and particularly the position of the nucleus. **Fat gathers at one end** of the cell, **crowding the nucleus to the opposite** extremity and displaces the cytoplasm to the periphery, mostly to that end of the cell occupied by the nucleus. **Pigment** may be in solution, more frequently in granules, and it is always found in the cytoplasm, **not in the nucleus. Vacuoles** are very common to most cells. These **vary in number and size** and are usually spherical cavities filled with fluid secreted by the protoplasm. The vacuoles **contract, often with considerable regularity**, and, as a rule, empty to the surface of the cell. Waste products are in this way eliminated from the body of the cell.

The constituents of a typical cell may then be summarized as follows:

1. **Cytoplasm**, the protoplasm **that surrounds the nucleus**, consisting of:
   - (a) **Spongioplasm**, a reticulum or fibrillar network;
   - (b) **Hyaloplasm**, a fluid portion, also called cytolymph;
   - (c) **Cell membrane**, often absent in animal cells.[1]
2. **Nucleoplasm** or **karyoplasm**, the protoplasm **of the nucleus**:
   - (a) **Nuclear membrane**, frequently absent;
   - (b) **Chromatin**, network that stains easily;
   - (c) **Linin**, closely allied to the chromatin but does **not stain**; dissolves in distilled water;
   - (d) **Nuclear sap**, a fluid perhaps analogous to the hyaloplasm;
   - (e) **Nucleolus**, spherical body that stains heavily;
   - (f) **Nuclear net knots**, or **karyosomes**, false nuclei that are nodal points formed by interlacing chromatin network;

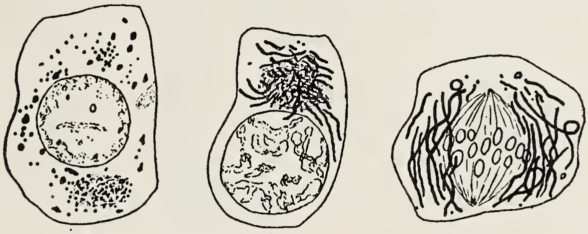
[1]Regarding the cell membrane, it is well to know that this is a purely relative term, just as a drop of chloroform in water, or a drop of water in chloroform, or a bubble of air in water, can be said to have a cell membrane. These are really *surface tension phenomena*, where the interphases of water-chloroform, etc., have equal resistance to each other. In the "cell membrane" we really have *naked protoplasm*, tending to round up just as the drop of water does in chloroform.

(g) **Centrosome**, a small spherical body often found in the cytoplasm of animal cells near the nucleus. It is looked upon as the dynamic center in cell division.

If the student is to study Medicine he will probably find an advantage in dividing the various definitely discernible substances in the cytoplasm, into Mitochondria, Plasmosomes, and Paraplasmic substances.

Mitochondria[1] (Fig. 27). These are little granules, rods, and threads in the protoplasm, **quite constant** in the various cell bodies, at least, of the animal world. In fact, one investigator insists that it is these mitochondria, rather than the chromosomes, which are the **bearers of heredity**; while another insists that they accumulate at both **poles** of the cell, and are converted into **secretory granules.**

Plasmosomes.[2] These are tiny granules distinguished from the mitochondria because they are concerned with the **housekeeping of the cell,** that is, with the assimilation of food materials, with forming various secretions, and with the excretion of waste matter. Plasmosomes have **not been seen,** but are supposed to be present because certain substances are produced in the cells which must be due to something physical or



a *b* *c*

Fig. 27. Mitochondria as they appear in the Sex Cells of Dividing Sperm of *Blaps.*

a. Scattered granular mitochondria.
b. Rod-shaped.
c. Rods drawn out around spindle. (After Duesberg.)

chemical. This is shown by the fact that the products of the cell form little swellings of various kinds. These swellings take a stain, and it is the particles which cause these swellings, or cell-products, which are known as plasmosomes. The cell-products consist largely of fat and carbohydrates, and may be stored in the cells. Cell products are called **cytofacts** or **metaplasm.** (This latter term is applied because such substance is due to metabolism.)

Golgi apparatus (Fig. 28). Very recently by a special staining method known as Golgi's silver impregnation method, it has been found

[1]While some medical men usually speak of *mitochondria,* and some of the older writers use the term bioplasts, plastidules, archoplasmic granules, plastosomes, plastochondria, chondrioconts, plastoconts and chondriomites, depending on the shape of the mitochondria, the name cytologists use is that of *Chondriosomes,* so that the student must think of *mitochondria* and *chondriosomes* as interchangeable terms.

[2]Medical men are inclined to use the term plasmosomes as here given, but cytologists use the term only to mean *true nucleoli.* These latter workers never use it in the sense we have given it in this book.

that there is an "internal reticular apparatus" consisting of a system of rods or network close to the nucleus, but associated especially with the dense protoplasm which surrounds the centrosome. In epithelial cells the network lies close to the free ends of the cells. The Golgi apparatus is probably found in all animal cells, though little is as yet known about it, except that there is a continuity from parent-cell to daughter-cells by a sort of mitotic division of it quite similar to the regular chromosome division. Prolonged treatment with osmic acid will make the Golgi apparatus visible.

Plastids are differentiated portions of protoplasm representing certain regions in which physiological processes are localized. They are quite common in plants and protozoa. In the former they are usually colored, such as the chloroplasts which are the chlorophyl-carrying organs. Each kind of plastid is supposed to serve a separate type of function.

Attraction sphere and **Centrosome.** These may be quite conspicuous

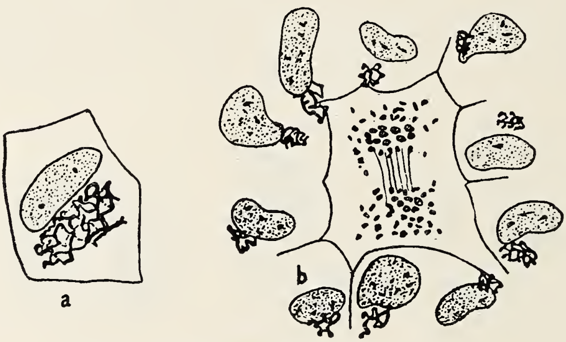


Fig. 28. Golgi Apparatus in Epidermal Cells.

a. Golgi network beside the nucleus in cell of a horse.
b. Same in skin of cat, but broken into small rods around the mitotic figure in the large central cell. (After Deinecka.)

although it is not known whether they are important or not in **cell-division,** shortly to be described.

Paraplasmic substances. These are the **foreign substances** which can be seen in the cytoplasm, but **which have not become part of the living** cell itself. Such are granules of **pigment** or **calcium, fat globules, various vacuoles filled with fluid, etc.**

"It is clear," says a recent writer, "that the construction of the cell is highly specialized in most cases for the function which it is to carry out, and that it is supplied with the most perfect mechanisms for these purposes. Some of these are evident in the form of contracted bands in the protoplasm, or in long, nerve processes ( ) like electric wires carefully insulated by sheaths of fatty material, or in mobile cilia which mechanically perform duties in the transportation of foreign particles. In others, the tools of their trade are recognizable in the form of the granules which seem to prepare **ferments** by which the chemical processes which the cells effect are carried out. While these are visible in many cases, there are others, even when we know that the most multifarious chemical reactions are being carried on, in which nothing of the mechanism is recognizable to our eyes."

In plant cells where the cell wall is quite thick, and in some of the animal cells, this cell wall is made up of **cellulose,** a substance quite clearly related to the starches, although there are other substances, such as **lignin** or **silica,** often associated with it, while in the cell walls of animals there is a **nitrogen containing substance,** such as **chitin, keratin,** and **gelatin.**

Where there is no distinct cell wall, there may be a **cuticle,** or **pelicle,** covering the entire cell. This may be considered a **lifeless secretion** just the same as is the cell wall produced by some of the vital activities of the cell itself. The **vacuoles** are little open spaces or **vesicles** of liquid enclosed within the protoplasm. They may be **persistent** or merely **temporary.** Vacuoles are quite common in protozoa. If they enclose food particles they are called **food vacuoles.** They may, by contracting suddenly, **eject their contents** and serve thus as **excretory organs.** As these vacuoles which eject their contents usually are formed again in the same place, they are called **pulsating** or **contractile vacuoles.**

CHAPTER VI

THE CHEMISTRY OF LIVING MATTER AND CELL DIVISION

ORGANIC CHEMISTRY, although named after the **organs** of living things, has come to be the study of **carbon compounds.** But as the three great chemical groupings of a living organism consist of **proteins, carbohydrates** and **fats** and all of these contain carbon, a large part of the study of organic chemistry is still devoted to living matter.

One of the great problems of Biology is to solve the riddle of how and where life originated. If the stars and planets surrounding our globe were at one time masses of intensely heated matter, no life could have been sent from one planet to another. Still it is interesting to know that the first elements appearing on a cooling star are the very ones which go to make up proteins; namely, carbon, oxygen, hydrogen, nitrogen, and sulphur.

It will be remembered that oxygen is the source of most of the energy of an organism, and that the cell is the unit of Biology, this cell being made up of various substances called **protoplasm.**

If a substance is of the consistency of glue and **non-crystalloid,** it is called a **colloid.**

Colloids are contrasted with **crystalloids,** such as sugar, salt, urea, etc., in fact, any of those substances which, when in solution, will pass through a membrane.

An **emulsion** is one fluid phase suspended in another. The fluids are said to be in suspension.

Most organic matter is colloidal, and some biologists believe that a colloid substance will ultimately be accepted as the biological unit in place of the cell.

Protoplasm, the substance of the entire cell, has somewhat the form of foam, although it differs from foam in having the alveoli filled with a thick liquid substance about the consistency of the white of an egg. The alveoli which make up the foam-like protoplasm, although having very thin walls, have walls thick enough so that diffusion is very slow and the substance itself is different in the alveoli themselves and the spaces between the alveoli.

All protoplasm does not show such alveolar composition. With the ultra-microscope much of the protoplasm appears as tiny particles. It is, therefore, supposed that this homogeneous mass is colloid in character, that is, consists of tiny granules which are suspended in a liquid medium. As there is not much difference between a colloid and an emulsion in this case, and as there are cases in which no alveoli can be seen, it is possible that alveolar substance and interalveolar substance may differ about as much or as slightly as a colloid and an emulsion.

The early workers on the cell saw very thin fibers in the protoplasm, and established the "filar" or "reticular" theories of protoplasmic structure. We now know that, if the alveoli are arranged in rows, the liquid between the alveoli will appear like threads, although we have not been able to find that these so-called fibers have any important function. These theories, therefore, are not among the important biological problems of the present time.

When cells are prepared and stained for study in the laboratory, they have many granules distributed within them. These may be coagulation products of the interalveolar protoplasm or, the cut ends of fibers or cell inclusions of various kinds.

The great mass of protoplasm is really an emulsion. The tiny bubble-like particles, or alveoli, and the liquid in which these float are called by the physical chemist "phases" of a "system." It can, therefore, be understood that the various surface phenomena which interest the physical chemist are to be found in the living cell, and any chemical knowledge of this nature, which the student of the cell can obtain, will stand him in good stead. Much of the activity of protoplasm can be explained by a study of surface tension.

It is to be borne in mind that protoplasm is never solid, although solid particles may be, and most often are, included within its liquid or semi-liquid mass.

Protoplasm is made up of both **organic** and **inorganic** substances.

Organic.

A. **Always present.**
- Enzymes.
- Non-enzymes.
  - Carbohydrates,
  - Proteins,
  - Fats,
  - Lipoids,
  - Extractors,
  - Intermediate products of metabolism.

B. **Not always present.**
- Pigments,
- Hormones,
- Aromatic compounds,
- Toxic compounds.[1]

The enzymes are continually attempting to produce an equilibrium in the cells. They are chiefly protein in nature and speed up the chemical

[1] It is, of course, to be understood that a substance is not toxic to the individual in the normal state. For example the poisonous sting of a bee or the poison gland of a rattlesnake is not toxic to the respective animal but to others.

reaction. They may be killed by light or heat. Their activities are **specific**, each type of enzyme doing only one particular type of work. **Every step** in the breaking down of proteids is done by a specific enzyme.

Inorganic.

A. **Always present,** and called **essential constituents.**
C, O, H, N, Ca, Na, K, Cs, Fe, Mg, H_2O, NH_4, CO_2, SO_4, PO_4.

B. **Sometimes present.**
I, Br, NO_2, NO_3, Zn, Ba, Cu, Mn, As, F, Si, Al.

Muttkowski has summarized the chemical constituents concerned in living matter as follows:

I. Constituents concerned with food.
  1. Those which compose food.
    A. Proteins—C, O, H, N, (S, P)—build protoplasm.
    B. Fats—C, H, O—energy and reserve. Certain P-fats enter into building up of all protoplasm (lecithin).
    C. Carbohydrates—C, O, H—furnish the energy and reserve in protoplasm.
  2. Constituents concerned in food synthesis.
     Mg, CO_2 (in plants only).
  3. Concerned with food storage—K.
  4. Katalysts—Fe, Ca, Mn, I.

II. Constituents concerned with Physiological Processes.
  1. Regulation (turgor, toxicity)—K, Cl, Na, Ca, I, Br.
  2. Sensory—P.

III. Constituents concerned with Structural Relations.
  1. Form relations—elasticity—N, Cl.
  2. Supporting tissues—C, Ca, Si, Mg, P, Fl, (S) in form of phosphates, carbonates, oxalates.

CELL DIVISION

Every living thing, plant or animal, begins its life as a single cell. Therefore, it follows that, if one wishes to understand how a many-celled animal (**metazoan**) (   ) comes to its adult form of life, one must find an original single cell and follow it throughout all its changes until it has come to adultship.

Every living cell grows if it obtains food, and, when it reaches its maximum size, splits in two. It may do this **equally** or **unequally**; that is, it may split into a very large and a very small part, or it may split equally into halves of like size and shape. There are then two cells where there was only one before. These two cells then grow until such time as they attain their maximum size when the same process is gone through again, so that in a short time there are four cells, then eight, sixteen, thirty-two, sixty-four, one hundred twenty-eight, and so on.

It is easy to understand what a division of cells may bring about when an old children's story is recalled. According to this story, a blacksmith expressed his willingness to shoe the King's horse on Sunday provided the King would pay one cent for the first nail, and double that amount for each additional nail. By the time the blacksmith had driven in the twenty-eighth nail, he had won more than a million dollars for the last nail alone. In the case of the tiny bacteria, which are single-celled plants, the division and increase may take place every few minutes so that in the course of a few hours there are millions upon millions of cells where before there was only one.

Writers on Biology commonly hold that there are two ways in which cell division comes about, but recent investigations tend to show that this may be erroneous and that all cell division is probably **mitotic.** One method is said to be the **shorter** and simpler way, in which the cell,

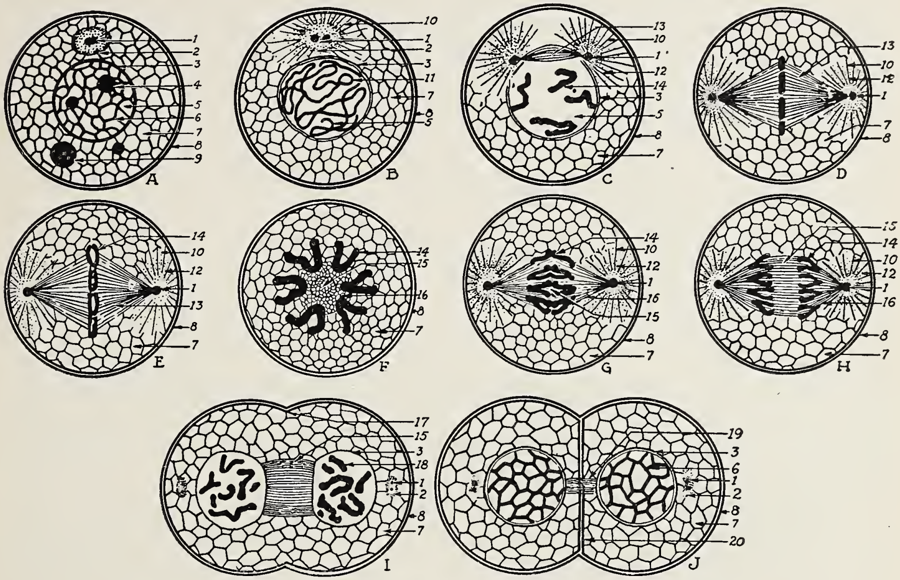


Fig. 29. Diagrams Representing the Essential Phenomena of Mitosis.
A, resting stage; B, early prophase; C, late prophase; D, mesophase; E, metaphase; F, end view of E; G, anaphase; H, late anaphase; I, telophase; J, late telophase.

LABELS.

1, centrosome.	7, cytoplasm.	14, chromosome.
2, attraction sphere (centrosphere).	8, cell wall.	15, central spindle fibers.
3, nuclear membrane.	9, vacuole.	16, mantle fibers.
4, nucleolus.	10, astral ray.	17, beginning of new cell wall.
5, nucleoplasm.	11, spireme.	18, chromosomes breaking down.
6, linin network and chromatin.	12, aster.	19, spindle remnants.
	13, spindle.	20, new cell wall.

(Redrawn from Jewell Models, by permission of General Biological Supply House, Chicago.)

without any previous changes that could be observed, **splits in two** parts. But the **longer method,** known as **mitosis** (Fig. 29), is the more common, and is the one which must be studied in detail if any understanding whatever is to be obtained as to how plants and animals evolve from the single original cell into the marvelous, complex organisms of adult life.

The cell, as described in the last chapter, has a network in the nucleus that stains quite easily and readily. When this network is not in the process of division the cell is said to be in the **resting stage.** In the higher forms cell division takes place only after **fertilization,** that is, after the male **sperm** has united with the female egg. The **chromatin** (stainable nuclear network) begins a process by which the stained part separates from the rest of the network, taking upon itself the shape of a single thread or **skein.** A little later, this skein of chromatin **breaks up into small particles** of various shapes. Some of the more common shapes are those bent like a horseshoe or like the capital letter L, and those that appear as little straight or bent rods. Such portions of chromatin are called **chromosomes.** As these chromosomes are **in all probability the most important physical particles** in the study of Biology, one must get this subject of **mitosis** and **chromosomes clearly in mind** or all that follows will be lost.

Just before the cell goes from the **resting stage** into the **skein or spireme stage,** the little centrosomes lying within the centrosphere break into two parts, one part migrating around the nuclear wall until it lies opposite the first half.

Formerly it was thought that it was due to these centrosomes that the chromatin breaks up into chromosomes, but as no centrosomes are found in higher plants, although the chromatin acts just as it does in animal cells, this explanation must be given up. Between the two centrosome parts in the animal cell there develops a series of very fine lines, which may be only a reflection of some kind, but which are very frequently seen when the cell is undergoing mitosis. These fine lines are called a **spindle,** readily recognized in the drawing. Four **periods** in cell division are usually mentioned:

The Prophases. This is the skein stage already referred to.

The Metaphase. Immediately after the chromosomes have appeared as small broken particles of chromatin, they gather at the **mid-line** or **equatorial region** of the spindles. Then the chromosomes split in two lengthwise, and the cell is said to be in the **metaphase stage.**

The Anaphases. Immediately after the chromosomes have divided lengthwise, one-half of them move toward one polar body and the other half toward the other. During the time the chromosomes have split and the time they have united about the centrosomes, the **cell wall** has indented until it meets the opposite indentation, thus forming two separate daughter cells.[1] This stage is called the **anaphase.**

The Telophases. This phase lasts from the anaphases until the time the cells again resume the resting stage.

It will be noted that the metaphase is used in the singular, whereas the other three have been used in the plural. This will be readily understood when it is remembered that these terms are only **convenient names** enabling us to discuss intelligently with others the whole subject of mitosis, and, so that when a given thing or event is observed during any particular time of the division of the cells, it can be written and spoken about in an understandable way.

The metaphase is only **that particular moment when the chromo-**

[1]In plants a new cross cell-wall often originates by a thickening of the central spindle fibres.

somes have gathered at the equatorial plane and are then separating. All the other phases cover a much longer period, and as they pass through **various stages**, are therefore used in the plural.

In different types of cells, all of these stages vary a little as to length of time and as to the method in which and by which particular **centrosomes, skeins** (also called **spiremes**), **spindles**, and **chromosomes**, arrange themselves. It is well to note that in the higher forms of plants, centrosomes have not been seen, and that there is a difference between plants and animals in the way the cytoplasm divides. In the **animal cells**, as shown in the drawing, the cell walls **indent** until the two indented portions meet, and the separation takes place in that way; whereas, in the plant cell the **cell-wall does not indent, but the wall** becomes thicker and thicker until a definite cell-wall has been grown for the two new cells.

There are exceptions as to just **when** and **how** the spindle forms. In some species of **salamander**, the spindle begins **outside of the nucleus**, and then, as the **nuclear membrane disappears**, the fibers **pass through the nucleus itself.**

THE REAL MEANING OF MITOSIS

The real significance of mitosis is found in the fact that the chromosomes (a more detailed study of which will be taken up as soon as the protozoa have been studied) split in two **lengthwise** and that the chromosomes are **practically the only known visible carriers of characteristics that pass from a parent cell** to become a new individual. Whatever an offspring is to obtain from its parents **must**, therefore, be already present in the chromosomes of the various **germ cells** of the parents, or it cannot be inherited by the offspring.

A little later it will be explained how the lengthwise dividing of the chromosome means that each new individual obtains one-half its chromatin matter from each parent. As the chromosomes carry the factors which produce the various characteristics each individual possesses, it follows that each new individual receives one-half of his various characteristics from the father and one-half from its mother, although usually these are not evenly distributed as to quantity, and possibly, quality. For example, we may, so far as external appearance go, resemble our fathers, yet have our mother's mental characteristics. One must, therefore, not confuse the characteristics **which can be seen and are very conspicuous**, with those which **may not be seen**, but **which may nevertheless be much more important.**

By remembering this statement one may understand the biologist's division of all cells in the body into two great groups. These two groups are known as **somatoplasm** ( ) and **germplasm** ( ). The latter consists of those particular cells which will reproduce offspring like the parent, while the somatoplasm consists of all the other cells of the body. It can be imagined from this that it is quite possible for the somatoplasm, or outer portion of the body (which is the only portion visible), to **cover up** many **important** or, at least, **latent** and **dormant characteristics** which an individual may have inherited, but which characteristics may **come forth at any moment.** In fact one can understand that such characteristics may lie dormant throughout the entire life of a parent and come forth only in the offspring.

MATURATION AND ELEMENTARY EMBRYOLOGY

Very low in the scale of life there is a differentiation into sexes; the **smaller, more active particle** is known as the **male gamete,** while the **larger, passive portion** is the **female gamete.**

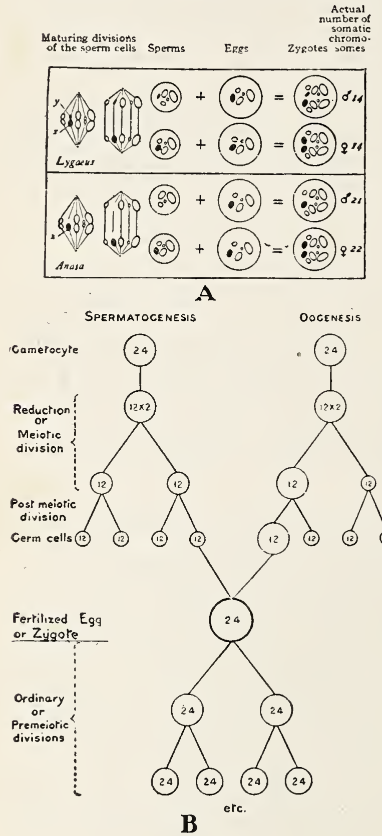


Fig. 30.

A. Diagram illustrating the behavior of the "accessory," sex-accompanying chromosome in fertilization. For the sake of clearness, but four other chromosomes are shown, and these four diagrammatically; accessory (x), solid black. (After Wilson.)
B. A diagram of the gametogenesis and fertilization.

In all higher forms **fertilization** is our starting point in any discussion of **embryology** or **development.**

There are apparent exceptions to this rule, such as those insects which give rise to young by **virgin birth,** a process called **parthenogenesis** ( ), and in the case of those animals in which several (as high as three) **immature generations may be present at the time of birth. This latter condition** is known as **paedogenesis** ( ).

Before fertilization, various changes take place in the germ cells which are to produce the **mature egg** and **sperm.** This process is called **maturation** ( ), (Fig. 30).

The early cells are called **primordial germ cells.** They are in a **state of rest** in all the higher animals for several years, or until the individual grows to **sexual maturity.** When this time has been reached, there are **three stages through which the primordial cell passes** before producing the mature ovum or sperm.

1. The primordial germ begins to divide **mitotically** (Fig. 31). The resultant cells are called **oogonia** and **spermatogonia.**

2. After a varying number of divisions, the many new cells thus produced go through a process of growth. They are then called **primary oocytes** and **spermatocytes.**

3. These then **"ripen"** or **"mature,"** after which fertilization can take place.

From what we shall soon learn regarding **Paramoecia** we know that the chromosomes are the important carriers of all physical **traits** inherited by a child from the parent. But, unless there is some method by which the chromosomes throw **off** one-half their number, each child, being the result of an egg and a sperm mating, would possess everything its mother possessed, plus everything its father had. A **super-race** would thus be produced which in a very few generations would be totally unlike any of its parents. One can imagine what it would mean to have every child twice as strong, and twice as tall, as its parents. It would not be long before men would be thousands of feet tall, and there would be little room for more than one or two people in the world. But nature apparently loves an **average,** and so somewhere, the chromosomes are halved.

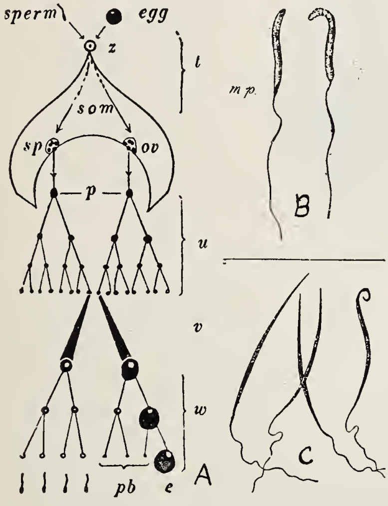


Fig. 31.

A. Diagram of the derivation of the sex cells. *z.,* the fertilized egg (zygote); *som.,* the body plasm (soma); *t.,* the development period during which the germ plasm and the body plasm are indistinguishable; *sp.,* spermary; *ov.,* ovary; *p.,* primordial germ cells; *u.,* the period of rapid increase in number and diminution in size (the number of divisions is much greater than shown); *v.,* the period of increase in size with differentiation of cytoplasm; *w.,* the two maturation divisions; *pb.,* polar bodies; *e.,* egg. (After Boveri.)
B. Spermatozoa of *Rena esculenta.* *mp.,* middle piece.
C. Spermatozoa of *Rana fusca.* (After Leydig.)

The ripening process is known as the **maturation division** (Fig. 30).

The egg varies from the sperm in the number of complete functioning cells it produces, although the chromatin acts alike in both cases.

From the primordial egg cell only one mature egg develops, while three undeveloped eggs, called **polar bodies,** are formed. These latter degenerate and have no known function. Each sperm cell, however, develops into four complete functional **spermatozoa,** any one of which may fertilize an egg.

Notwithstanding this difference, both sperm and egg cell have the same number of chromosomes characteristic of the species. This full quota of chromosomes is called the **diploid number.**

The primordial cells (those which are to become eggs) begin their growth very early in the embryo. Usually, a quantity of yolk is deposited to serve as food for the embryo which is in turn to develop from the egg.

The chromatin in the nucleus

gathers in a thick mass towards one side of the nucleus. This is known as the **synapsis stage.** From this thick mass of chromatin there will emerge just one-half the number of chromosomes usually found in cells of the particular species we are studying. Such cells are said to have the **haploid number** of chromosomes.

Each of these chromosomes is double, the two parts either lying side by side, or end to end. This stage of half the number of chromosomes (but where each is a double chromosome), is called **pseudo-reduction.** Real **reduction** then follows. The two parallel portions of each chromosome divide longitudinally, while the entire chromosome contracts into small four-portioned chromosomes, each of which is called a **tetrad** (Figs. 31 and 33). A mitotic figure now forms and moves toward

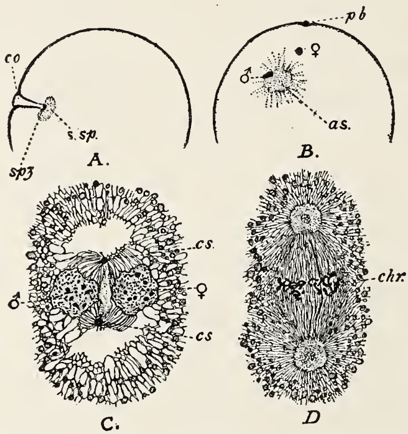


Fig. 32. Fertilization of the Amphibian Ovum.

A, outline drawing of a section parallel to the axis of the egg; the superficial pigment of the animal hemispheres of the egg is indicated, but the yolk granules are omitted. *co.*, entrance cone; *spz.*, spermatozoon lying at the bottom of the entrance funnel; *s.sp.*, spermsphere.

B., a meridional section through the egg at a later stage; ♂, sperm nucleus, also called the male pro-nucleus; ♀, egg-nucleus, also called the female pro-nucleus; *as.*, sperm-aster; *pb.*, polar body. The size sperm-and egg-nuclei has been exaggerated.

C, portion of a section through an egg showing an early stage in the formation of the fertilization spindle, highly magnified; ♂ sperm-nucleus; ♀, egg-nucleus; *cs.*, centrosomes.

D, portion of a section of an egg showing the early stage of the metaphase of the fertilization spindle; *chr.*, the chromosomes derived from the sperm- and egg-nuclei lying unevenly, but still in two distinct groups, in the equatorial plane. (After Jenkinson.)

the outer rim of the egg. The nucleus divides equally, so that one-half of each tetrad passes to a daughter nucleus.

Although the nucleus divides equally, the cytoplasm does not. This produces one large egg cell and one small particle, this latter with one-half the chromatin, but with little or no cytoplasm. The smaller portion is the first **polar body.** This is pinched off from the egg cell proper.

Both egg cell and polar body now begin to divide again. It is in this second division that each remaining half-tetrad (now called a **dyad**), separates into its two component parts, one going to each daughter nucleus. Thus the second polar body is formed which is also pinched off from the egg cell proper. Often the first polar body again divides to form two tiny cells, but none of the polar bodies perform any actual known function for the organism. From this account we note that four cells have formed from the primordial egg cell—the egg proper and three polar bodies. Two of the polar bodies are the result of the first polar body dividing in turn.

It is of great importance to note that the order of development may change in different species. For example, some polar bodies never divide, while in some species maturation takes place before, and in others after fertilization.

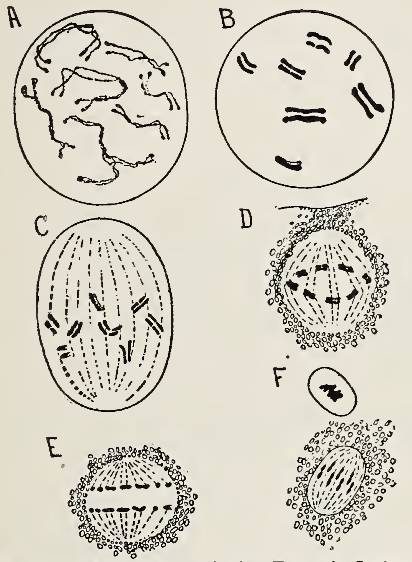


Fig. 33. Maturation of the Egg of *Cyclops* (the full number of chromosomes is not shown).
A, chromosomes already split longitudinally; *B*, chromatin masses with indication of transverse fission to form the tetrads; *C*, the young tetrads arranging themselves on the first polar body spindle; *D*, tetrads in first body spindle; *E*, separation of the dyads in the same; *F*, position of the dyads in the second polar body spindle, the first polar body being really above the margin of the egg. (After Rückert.)

We shall see in our study of plants that this reduction-division is not confined to the animal world.

The male cell — the sperm — passes through similar changes to that described for the egg cell, except that there are no polar bodies formed.

In Biology we always think of the reproductive cells as the **germ plasm** which alone carries on from parent to offspring all things that can be inherited. It must, therefore, follow that there is something in the germ plasm which determines what the offspring is to be. These determining factors must be in the chromosomes because it is only the chromosomes which pass from parent to child. But there can be a considerable "change-about" of the chromosomes. For example, if we have four chromosomes numbered 1, 2, 3, 4, either 1 and 2 may be thrown out in the reduction division, thus leaving 3 and 4; or 1 and 3 may be thrown out, leaving 2 and 4; or 2 and 3 may be thrown out, leaving 1 and 4; and so on.

If it be remembered that quite a number of combinations can be made in this way in both the egg and the sperm, it is readily understood that several times this number of combinations can be brought about by a mingling of sperm and egg after fertilization, when the reduced sperm cell unites with the reduced egg cell. When we come to the study of **Genetics**, we shall enter into this phase more thoroughly.

It will, of course, depend upon what characters are thus carried by the two mating chromosomes as to what characters the new organism will possess. It is this assorting and rearrangement of chromosomes which is in all probability the cause of **variations within a given species.** This is by no means the same as saying that it is the cause of **new species.** This distinction must be kept clear.

The diploid number of chromosomes is reduced to the haploid number by a union of the chromosomes, two by two, as already stated. But this union in groups of two is by no means haphazard. An understanding of this can best be seen in animals where the chromosomes are different both as to shape and size. The squash-bug **(Anasa tritis)** is a good example.

In these bugs the chromosomes occur in two sets, larger ones and smaller ones (Fig. 30). During pseudo-reduction, the larger unites with a larger one, and the smaller with a smaller one, and so on. All the resulting tetrads are symmetrical.

The sum total of all the character-factors, which are received from the parents of an animal at the time the egg is fertilized, are contained in these two sets of chromosomes. In some insects **virgin birth** is not uncommon. In these cases a complete individual develops from the mature egg alone—that is, from the one having only one-half the definite number of chromosomes normally present in each cell of that species. This shows that each set of chromosomes contains all that is necessary for a complete individual. We, therefore, think that the linking of a similar chromosome from the male and a similar one from the female must be for the purpose of bringing similar important factors together so as to strengthen such factors. A fuller discussion of inheritance will be left for the chapter on genetics.

FERTILIZATION

The **union or fusion** of the sperm nucleus and the egg nucleus is known as **fertilization** ( ). The spermatozoon is composed of three parts, head, tail, and mid-piece (Fig. 31). The head is largely nuclear material and is the only portion which actually enters the egg and fuses with it. Sperm may enter an egg either before or after maturation of the egg is completed.

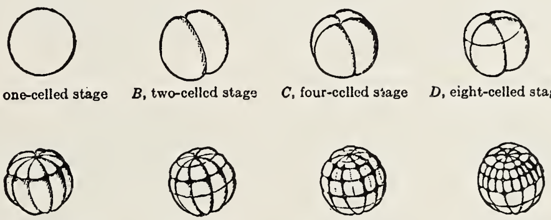
After the sperm cells have passed through the maturation process a great mass of them are secreted at one time from the spermaries. If an animal lives in water, the sperm float about in that fluid, otherwise enough liquid is excreted to make it possible for the sperm to float about until coming in contact with an egg.

Among all higher animals there are special **copulatory organs** which vary considerably in different animals but which, in all cases, serve to bring egg and sperm together.

There is a great attraction between these germ cells of the different sexes which cause their union and fusion, though what this attraction is has not yet been discovered.

If the sperm enters the egg after the latter has matured (which is by far the more common method) certain changes begin taking place at once.

The sperm nucleus is called the **male pronucleus** (Fig. 32) after it enters the egg, while the nucleus of the egg is known as the **female pronucleus.** There is often a special aperture in the wall of the egg, called a **micropyle,** ( ) through which the sperm enters. Usually only one sperm cell enters an egg. Various changes are set up at the very moment the sperm enters the egg, causing the egg membrane to become impervious to other sperm. Sometimes, if the egg be old or diseased, this process may not begin soon enough, so that several sperm enter the same egg. This is called **multiple fertilization.** There are



A, one-celled stage *B*, two-celled stage *C*, four-celled stage *D*, eight-celled stage

E, sixteen-celled stage *F*, thirty-two celled stage *G*, sixty-four celled stage *H*, many-celled stage

Fig. 34. Cleavage of Frog's Egg.

some species in which this multiple fertilization occurs normally. Monstrosities are often formed in this way.

When the two pronuclei unite, they form a **fusion nucleus** (Fig. 32), also called the **first segmentation nucleus.** The egg is then said to be fertilized, or **impregnated.**

The **full quantity of chromosomes** is now again present, and there seems to be an impulse brought with them which starts the egg dividing. This division of the fertilized egg is known as **segmentation** or **cleavage** (Fig. 34). This is brought about by ordinary **mitosis,** and these first cells, which come into being by the splitting of the fertilized cell, are called **blastomeres** ( ). The chromosomes do not divide longitudinally in these blastomeres, but each new cell receives **one-half** of the material brought by each of the parent cells. In this way **every cell** in the body **gets an equal amount** of chromosome material from each of its parents. And in this way also, **every cell** in the body of an individual **has exactly the same number of chromosomes** within it that every other cell has.

Each succeeding division of cells produces cells a trifle smaller than the parent cell.

The cells divide differently with different quantities of yolk. Usually the first **three cleavage planes are perpendicular to each other.**

If the yolk is evenly distributed, the newly formed cells will be more or less of equal size.

Often the **yolk** collects at the **lower portion** of the egg. This is undoubtedly due to the force of gravity. In such cases the **protoplasm** gathers at the upper end. The **upper end** is then called the **active, formative**, or **animal pole** and the **lower** the **passive, nutritive**, or **vegetable pole.** The **polar bodies** are usually **freed at the formative pole.** This causes the blastomeres at the nutritive pole to become larger, and divide less rapidly than those in the region where there is an excess of protoplasm. In fact the yolk may be so excessive as not to permit any division at all within it.

Two forms of segmentation are usually given:

A. **Total segmentation.**

I. **Equal:** In which there is little yolk material and that well distributed. (Illustrated in most of the lower invertebrates and mammals.)

II. **Unequal:** In which a moderate amount of yolk accumulates at the passive pole. The cells at the active pole are more numerous and smaller than at the passive. (Illustrated in many mollusks and in Amphibia.)

B. **Partial segmentation.**

I. **Discoidal:** In which there is an excessive amount of yolk with the nucleus and a small mass of protoplasm occupying a disc at the active pole. This disc alone segments, and the embryo lies upon the yolk. (Illustrated in the eggs of fishes, birds, and reptiles.)

II. **Peripheral:** In which an excess of yolk collects at the center of the ovum, with the protoplasm at the periphery. The dividing nuclei assume a superficial position and surround the unsegmented yolk. (Illustrated in the eggs of insects and other arthropods.)

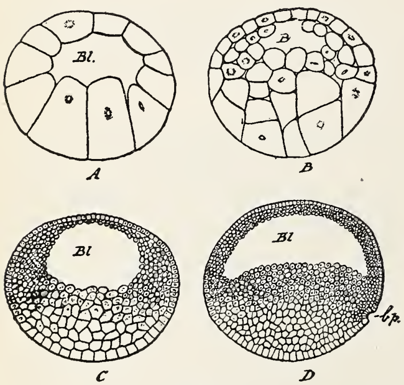


Fig. 35.
A, vertical section through a segmenting ovum in the blastula stage. *B, C* and *D*, similar sections through later stages. *Bl.*, segmentation cavity or blastocœle; *bp.*, blastopore. (After Morgan.)

BLASTULATION AND GASTRULATION

As segmentation continues the blastomeres remain attached to each other and form a **spherical mass** (Fig. 35). If the individual cells **project out from the mass** and the sphere is more or less solid, it resembles a mulberry and is called a **morula**

( ), but if it becomes a **single layer** of cells and is **hollow,** it is known as a **blastula** ( ). In the latter case the hollow portion in the center is filled with a fluid. The hollow space itself is called the **segmentation cavity.**

If this blastula **indents** (just as though one were to take a hollow rubber ball and push in one side with a finger), there are **two layers in the indented region.** The **outer layer** is called the **ectoderm** or **epiblast,** and the inner the **entoderm, endoderm,** or **hypoblast,** while the entire two layered mass is known as a **gastrula** ( ). The **indentation** is also called **invagination** and **gastrulation** (Fig. 36).

Having indented, the indented portion draws together to form a single mouth-like opening. This opening is the **blastopore** ( ), and the newly made cavity surrounded by **entoderm** is the **primitive intestinal tract or archenteron** ( ). In our study of the hydra it will be found that that animal grows thus far and then remains throughout its entire career in the gastrula stage.

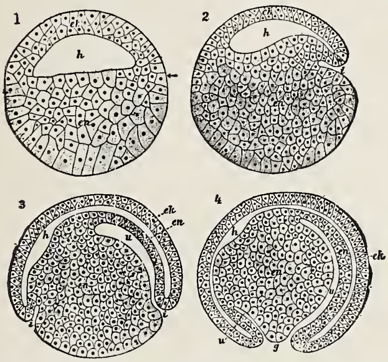


Fig. 36. Formation of the Gastrula in Amphibia. Diagrammatic Longitudinal Section.
1, Blastula; 2, the invagination has begun at *i* (the corresponding place in 1 is indicated by an arrow); the invagination is in the form of a furrow, but does not yet surround the egg; 3, the invagination is proceeding; 4, perfect gastrula; the archenteron is almost filled with a projecting part of the hypoblast, which is later dissolved and absorbed by the embryo. *ek.,* ectoderm (light); *en.,* entoderm (shaded); *g.,* mouth of gastrula; *h.,* segmentation cavity; *i.,* invagination furrow; *n.,* archenteron. (After Boas.)

In higher forms a **third layer** is formed between the ectoderm and entoderm known as the **mesoderm.** Animals having these three germ layers (Fig. 37) are called **triploblastic** ( ). **All tissues and organs are derived from some one or more of these germ layers.** To study this development is the special province of **Embryology.**

Often certain blastomeres grow more rapidly than others in the same embryo. Such is the case with frog's eggs (Fig. 38). This results in the more rapidly growing cells surrounding those which divide more slowly. A growing of one set of cells over another is called **epibole** ( ). The separation of the germ layers or membranes by splitting apart is known as **delamination.**

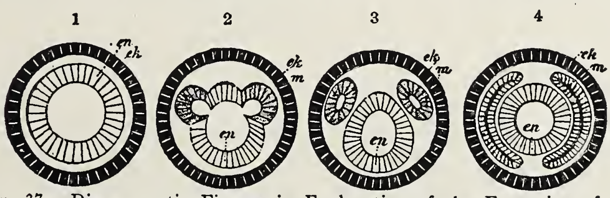


Fig. 37. Diagrammatic Figures in Explanation of the Formation of the Third Germ Layer—the Mesoderm.
1, youngest, and 4, the oldest stage.
ek., ectoderm; *en.,* endoderm; *m.,* mesoderm. (After Boas).

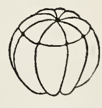


Fig. 38. Frog's Egg, Showing Proportionate Increase of Smaller Cells at Top of Egg.

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CHAPTER VII

HISTOLOGY OF THE FROG

EVERY living individual, plant or animal, which is able to live an independent existence and which possesses the four characteristics of **irritability, ability to take and digest food, to grow by intussusception,** and to **reproduce its own kind,** is called an **organism.**

The higher organisms are made up of separate specialized organs, each organ consisting of a series of tissues, and each tissue, in turn, made up of a sheet of similar functioning cells.

The **cell** is the **biological unit,** and the modern world attempts to explain all living things in terms of cellular construction.

It can be appreciated readily that the cell is intensely important in the study of all living organisms when it is realized that **every living thing,** plant or animal, originally grows from a **solitary cell,** and any tiny structure capable of producing so wondrous an animal as the frog or still more wondrous an animal as the human being, is certainly of importance.

In fact, if one could find **all** the **possibilities** of any given cell, and then find **why it has these possibilities,** and just **how and why** it develops into the particular structure that it does and no other, the riddle of life would be solved.

It must be remembered that every living thing starts life as a single cell, and then, if it is to become a **multicellular animal,** it passes through a **cell-dividing stage.** Some plants and animals remain in the one-celled stage, while others, as soon as they begin to divide, **adhere together and form tissues,** which in turn develop into organs. This means that a study of the **origin, development, and content** of the unit cell gives us a sort of bird's-eye view of how living things work and grow. A study such as this presents a more complete view than could be obtained in any other way.

First, therefore, it is necessary to know the different kinds of tissues that may be encountered. These are grouped under four distinct heads:

1. **Epithelial.**
2. **Connective.**
3. **Muscular.**
4. **Nervous.**

1. **Epithelial tissues** (Fig. 39) are always **surface tissues.** They lie in layers with a small amount of **intercellular** substance. The **surfaces of organs,** the **linings of cavities** of organs, and the **lining of glands, blood vessels,** and **ducts** of all kinds, possess this tissue. In fact, it is

surface tissue whether lying on the internal or external surface of an organ.

There are, however, **various types of epithelial tissue** and these are named from their shape. For example: **Flattened** or **squamous** epithelium, easily obtained from the outermost skin of the frog during the time it molts or from the peritoneum, is composed of cells which are broad and flat with a rounded **nucleus** near the center.

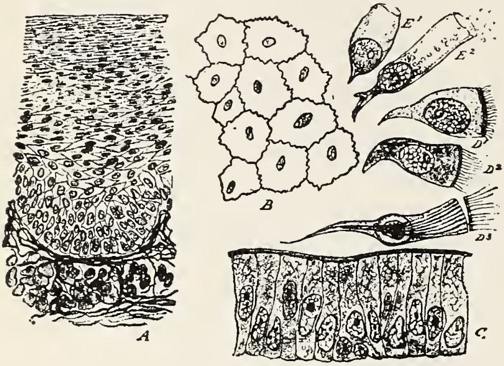


Fig. 39.

A, stratified epithelium from the oesophagus of the rabbit, seen in section. In the lower part of the figure the connective tissue and muscular layers are shown. B, squamous epithelium from the mesentery of the Frog, silver nitrate preparation; *E1, E2,* goblet cells from the frog's mouth; *D1, D2,* isolated ciliated epithelium cells from the frog's mouth; *D3,* an isolated ciliated cell from the gill of the mussel. C, columnar epithelium from the intestine of the frog. (From Bourne, after a drawing by Dr. E. H. Schuster.)

In the mucous layer of the intestine, we find what is known as **columnar** epithelium, because the cells are shaped like columns, while in many places such as in the outer skin, there are **transitional stages** between these two types of tissues which have some of the characteristic shape of both flat and columnar epithelium.

If these cells are several layers deep, they are called **stratified epithelium.**

Should they have tiny hairlike substances (called **cilia**) at their outer ends, they are known as **ciliated** epithelium. Ciliated epithelium may have almost any shape—**columnar, cuboid,** or **flattened.** Ciliated epithelium is found in the **mouth, throat,** parts of the **peritoneal lining** of the body-cavity, inner lining of the **oviducts,** in the mouths of the ciliated funnels of the **kidney,** in the **ventricles** of the brain, and, in very early life, even on the outer surface of the body.

2. **Connective tissue** (Fig. 40) serves to support and hold together various parts of the body. In this type of tissue, the **intercellular substance** is quite abundant as contradistinguished from nearly all other types, and it is interesting to note that nearly all of the connective tissue is derived from the middle **germ-layer** or **mesoderm** (   ). The intercellular substance changes in many ways. It may remain soft, or become **fibrous and even change into bone.** The principal types of this tissue are as follows:

White fibrous connective tissue, most widely distributed, and easily obtained from the membranes connecting skin and body-wall. Under the microscope it appears as a clear gelatinous substance in which many fibrils are embedded. The fibrils are **unbranched** but have a characteristic **wavy appearance**; often they are united in bundles and run in all directions. A few **yellow elastic fibers** may be scattered among the white. These are always **straight**, however, and not wavy. If the tissue should be treated with acetic acid, the white fibers swell up and disap-

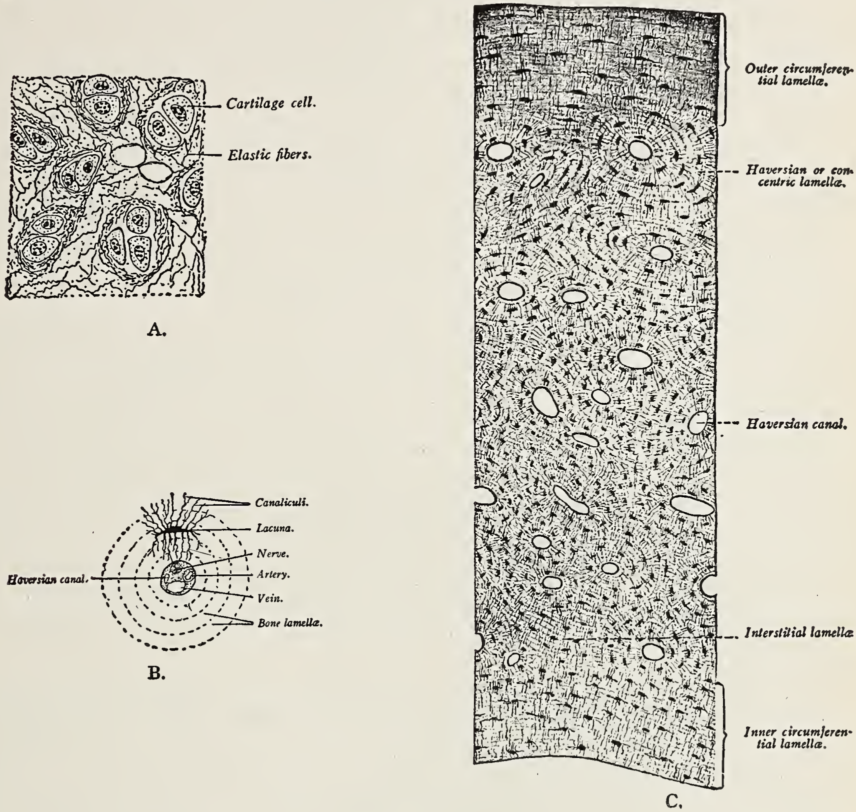


Fig. 40.

A. Elastic cartilage.
B. Haversian system with one lacuna sketched.
C. Segment of transversely ground section from shaft of a long bone, showing all lamellar systems. (From Böhm and Davidhoff.)

pear. The **yellow are not affected.** The yellow fibers may also branch, and when cut they **do not curl** as do the white fibers. In the various spaces of the **matrix** ( ) **connective tissue corpuscles** or cells may also be found, varying in form and appearance, often united with neighboring cells to form an **irregular network,** the meshes of which are filled with intercellular substance. White fibrous tissue varies in **consistency** and **texture** in different parts of the same animal. The loose tissue which binds muscles together is known as **areolar** ( ), and is composed of sheets and strands intersecting each other in all planes. It is areolar which forms the **fascia** for each muscle, and is modified into a **tendon** at the end.

The looser tissue of the lymphatic glands is called **adenoid** (   ) and is composed of an irregular network of sheets and strands which forms a fine meshwork of supporting cells.

The various **ligaments** uniting the bones are formed of a dense and non-elastic variety of white fibrous tissue. White fibrous tissue is also found in the **cutis** of the skin, the **submucosa** of the alimentary canal, in the walls of the blood vessels, in the substance of glands, and in the capsules covering various organs.

Adipose tissue is regarded as a form of connective tissue in which the cells have enlarged by being gorged with fat. The nucleus here lies toward one side of the cell, while the cell-wall and a thin **pellicle** of **protoplasm** surround the **fat globule.**

Cartilage is a dense and massive variety of connective tissue. The predominant type in the frog is known as **hyaline** (   ), the **matrix** of which appears **transparent** and **homogeneous** (   ), although it really consists of numerous fibers of different types which can only be observed after chemical treatment. The cells in this type of tissue are contained in little rounded spaces, or **lacunae**, scattered quite irregularly through the matrix. There may be two or more cells in one lacuna, which leads to the belief that the cells may have been formed quite recently by a division of the parent cell. An intercellular substance is deposited around each cell, there being a sort of partition grown between each of the cells which gradually increases in thickness and presses them farther and farther apart. The outer surface of the cartilage is covered by a thin layer called the **perichondrium** (   ).

Hyaline cartilage is found at the **ends of the bones** of the limbs, between the spinal vertebrae and **the ends of their transverse processes,** at the **tip of urostyle,** in the **pubis** of the pelvic girdle, in the **hyoid,** and the **cartilage of the larynx** and of **both ends of the sternum.** It also forms the **basis of the cranium** and the **central axis** of the **lower jaw.**

Calcified cartilage is that which contains a deposit of **lime salts in the matrix.** It is found in the **pelvis of old frogs,** in the **suprascapula,** and at the **ends of the larger bones** in the limbs such as the head of the humerus and femur.

Bone structure is quite similar to that of cartilage and also contains cells embedded in a solid matrix. In bone, however, the matrix is made more firm by a deposit of **carbonate** and **sulphate of lime.** If the bone is immersed in acid so as to remove the lime solids, the histological structure of bone is quite like that of cartilage. It does not follow from this, however, that bone is merely calcified cartilage, for bone and cartilage differ from each other both histologically and chemically. Cartilage often is followed by bone, but when it is, the cartilage has been broken down and the bony tissue has taken its place. We speak of two types of bone, namely, **compact**, and **spongy** or **cancellous.** The former is firm and dense while the latter is composed of a comparatively loose arrangement of plates and parts, thus lacking the strength of compact bone. The spongy, or cancellous, type is found in the **center of the vertebrae** and to a small extent within some of the long bones. Bones such as the femur and, in fact, all of the long supporting bones in the body, must be rather compact. A cross section of any of these long bones will show the outer hard portion of a compact bone with an inner soft **marrow** and a thin surface layer over the outside, called the **periosteum** ( ). This latter is quite similar in structure to the perichondrium surrounding cartilage. The arrangement of the layers in compact bone is **concentric,** and the layers themselves are known as **lamellae** ( ). These lamellae contain numerous lacunae in which the bone-cells proper are found. Fine branching tubes, or **canaliculi,** containing processes from the bone-cells, are given off from the lacunae and extend in all directions, often **anastomosing** ( ) with the neighboring canaliculi.

Bones grow like trees in that successive layers are added to the outside. The cells forming the inner layer of the periosteum, known as **osteoblasts** ( ), are continually giving rise to new bone cells, which cause new layers of bony substances to be deposited between the periosteum and the old bone. New layers, however, may be added on the inner surface between the walls and the marrow cavity.

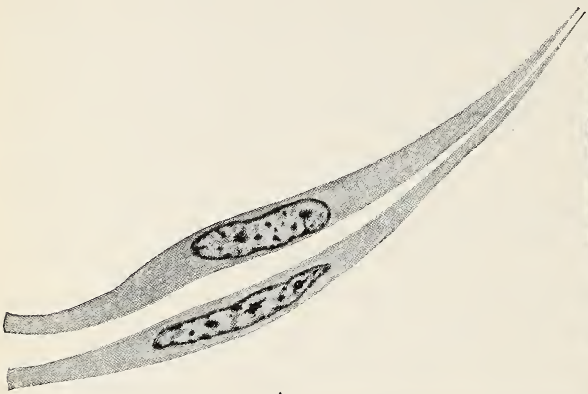
Muscle tissue (Fig. 41) is composed of elongated cells, or fibers, united by connective tissue, as already mentioned. There are three types, the **voluntary or striated,** the **involuntary or unstriated,** and the **automatic or branched,** a sort of combination of the first two, known as **heart-muscle.**

The nonstriated fibers are rather simple in structure, commonly **spindle-shaped** with a single nucleus near the center, often elongated. The ends of the fibers may be branched, but are not usually so. The length of the fibers varies to a considerable extent. They may be very narrow, or short and comparatively thick. In the involuntary muscle fibers there is usually no cross striation, but one may find delicate longitudinal strands, called **fibrillae,** usually considered to be the **contractile elements** of the cell. The cell wall itself is thin and transparent. Nonstriated muscles respond to stimuli quite slowly, being also somewhat slow to relax after the function has been performed. It is found particularly in those branches of the body where sudden movement is not required, such as in the **muscular coats** of the **alimentary canal,** in the **walls of blood vessels,** in **various ducts,** in the **lungs,** in the **urinary** and **gall bladders,** and around **glands in the skin,** and also in the **iris** and **ciliary muscle** of the eye.

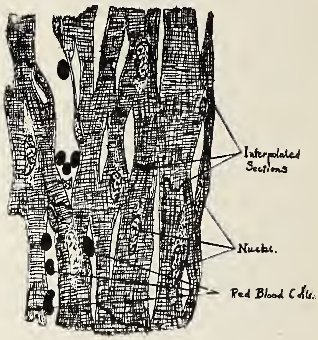
Striated muscle fibers are more complicated in structure than nonstriated muscles. They possess several **spindle-shaped nuclei** scattered throughout the cell, each nucleus surrounded by a small amount of

undivided cytoplasm (·). There is a thin but well defined cell wall, called the **sarcolemma** ( ), best seen where the contents of the fiber are crushed or broken apart.

Each fiber of voluntary muscle is regarded as a single cell with numerous nuclei scattered throughout its cytoplasm. In the early stages of development there is but one nucleus in each cell in the voluntary muscle, but as the fiber grows and the nucleus rapidly divides, while the



A.



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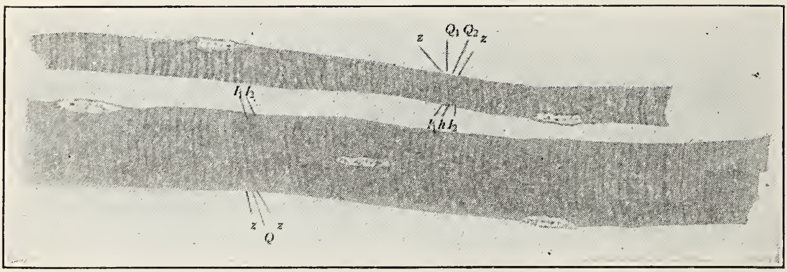


C.

Fig. 41.

A. Smooth muscle fibers from the bladder of a Frog.
B. Heart-muscle syncitium.
C. Striated muscle fibers from the muscle of a cat. Q, cross discs separated from each other by interposed discs *I1, I2*. *zz* shows the stripe in which granules are visible. *h*, is shown as a center-disc, situated within the cross-disc. (From Krause-Schmahl "Histology," by permission of The Rebman Co.)

cytoplasm does not, there are naturally a number of nuclei within a single cell wall.

There is here **both a longitudinal** and a **cross striation** consisting of alternate light and dark bands. **Sarcostyles** ( ), or **fibrillae,** which extend the entire length of the cell, are the cause of the longitudinal striations. These fibrillae, as in the unstriated muscle fibers, are the contractile elements. They are kept apart by a semi-fluid substance, called the **sarcoplasm.** The fibrillae themselves are arranged in bundles or muscle columns separated from each other by a thicker layer of sarcoplasm than is found between the fibrillae. The cross striation is due to the fact that the fibrillae really consist of **segments** or **sarcomeres** ( ). The segments are separated from each other by a very fine dark line, called **Krause's membrane.** This membrane extends not only across the individual fibrillae but across the entire sarcoplasm between the fibrillae of the fiber. Krause's membrane is bordered on each side by a more or less clear and **lightly stained band** formed by the ends of the two adjoining segments. The middle portion of each segment forms a so-called dark band, and across the center of this band there extends a second very delicate membrane known as the **line of Hensen.** Should the muscle fiber be cut transversely, the cut ends of the muscle columns present a number of **polygoneal areas,** known as **Cohnheim's fields.** The spaces between the fields are filled with sarcoplasm, and the dotted appearance is due to the cut ends of the tiny individual fibrillae.

The **muscle fibers of the heart** are different from either the striated or unstriated fibers, although heart muscle does present cross striations, and, as in ordinary striated muscle, **each fiber also possesses more than one nucleus.** Further, every heart muscle cell has branches which connect with other branches, thus forming a continuous network, called a **syncitium** ( ). (A syncitium represents a group of cells whose separating **walls or** membranes have been lost, reabsorbed, or failed to form.)

4. **Nerve tissue** (Fig. 42) is made up of nerve fibers and **ganglion cells** ( ). A nerve cell, together with all of its processes, is called a **neuron.** Each nerve is made up of a bundle of fibers held together by connective tissue and surrounded by a common sheath. The central strand of a nerve fiber is called the **axis cylinder.** About this is found the **medullary sheath** ( ), (also called the **white substance of Schwann**), then a delicate external membrane called the **neurilemma** or **sheath of Schwann.**

There are various **constrictions** to be seen in any long nerve. These are known as the **nodes of Ranvier.** It is at these nodes that the white substance is interrupted although the axis cylinder and neurilemma continue.

The nuclei surrounded by a small amount of protoplasm are found immediately beneath the neurilemma. There are also various **oblique markings** across the medullary sheath between the nodes of Ranvier known as **incisures of Schmidt.** The axis cylinder of a nerve is merely a continuation of a ganglion cell, being made up of very fine fibrillae, with an intervening fluid substance. The white or medullary substance contains a large amount of fatty material, called **myelin** ( ). This sheath is supposed to act somewhat as an **insulator.**

Nerve fibers **and muscle** fibers **develop differently.** The former are a **composite structure** formed of cellular elements which originate in various ways. For example, the nerve sheaths, though coming in contact with and surrounding the axis cylinder, have a totally different origin from the cylinder. It is interesting to know that in its development the **axis cylinder is the first to make its appearance and comes from the exterior or ectodermic layer of the organism in which it develops,** while the cells forming the sheath come from the mid or **mesodermic** layer.

The **negative manner** of testing any of our scientific laws and principles may be illustrated here by calling attention to the fact that much of our knowledge of the position of nerves in various parts of the body does not come from our ability actually to trace them throughout their entire course, but by tracing the **dying** portion of an **injured** nerve. Having found that the cell is the important part of a nerve, and that whenever a fiber is cut between its cell and the termination of its

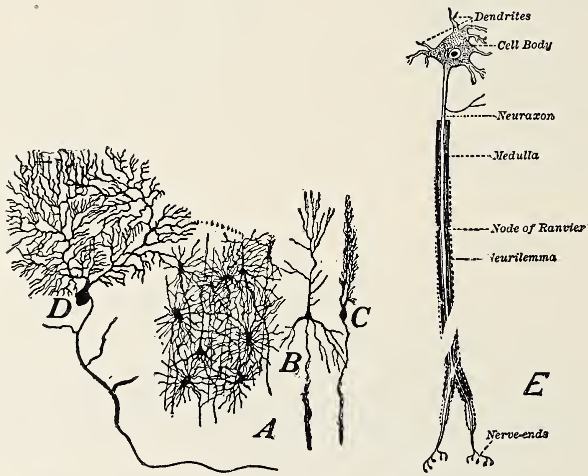


Fig. 42.—*Neurons of Various Types* from Higher Animals.

A, a complex of neurons from the cerebrum; B and C, neurons from the cerebellum; D, a single neuron from the cerebrum. E, diagram of a neuron or nerve unit.

processes, it is that part still attached to the cell which will grow again, experimenters have cut nerve fibers and then watched that portion no longer connected with the cell proper, degenerate. By watching this and then observing those parts of the body which degenerate along with the dying nerve fiber, it is easy to see where the fibers actually pass and terminate.

Nerve centers is the name given to those parts where several nerve cells are grouped together such as in the brain, spinal cord, ganglia, and the various ganglionic masses of the sympathetic system. The centers themselves consist of ganglion cells and their fibers, together with the connective tissue which holds them together, and the little vessels which supply them with nutriment and carry away waste products.

Ganglion cells are usually quite **irregular** in outline with a **single**

nucleus near the center. The **cytoplasm** is **rather granular** and, with certain stains, shows a network of tiny fibers connected directly with the fibrillae of the nerve fiber as well as with other processes of the cell. There are several kinds of processes. The **axis cylinder process,** already mentioned, requires a sheath and becomes part of a nerve fiber, and the **protoplasmic processes,** sometimes several in number, are shorter than the axis cylinder and usually branched.

The cells themselves are designated as **unipolar, bipolar,** or **multipolar,** in accordance with the number of processes they may give forth. Unipolar ganglion cells are found in the sympathetic ganglia.

CHAPTER VIII

SUMMARY OF THE FROG

IT has now been seen that the frog is a **cold-blooded animal**, an **amphibian**, and a **vertebrate**.

Its **external features** have been observed.

Its **internal structure**, consisting of a series of organs known as **systems**, have been studied. These were:

(a) The Digestive System.
(b) The Circulatory System.
(c) The Respiratory System.
(d) The Excretory System.
} Concerned with Metabolism.

(e) The Nervous System.
(f) The Endocrine secretions.
} Concerned with regulation and control.

(g) The Muscular System.
(h) The Skeletal System.
(i) The Integumentary System.
} Concerned with locomotion, support and protection.

(j) The Reproductive System. Concerned with the propagation of the race.

It has been learned that organs are composed of **tissues**, and tissues in turn, of **sheets of similar functioning cells.**

There were four general types of tissues:

(a) **Epithelial.**
(b) **Connective.**
(c) **Muscular.**
(d) **Nervous.**

Tissues may also be classified according to their **functional** and **structural** character. For example, according to **function**, the epithelium is grouped as follows:

(a) **Glandular**, which consists of **secreting** cells.
(b) **Sensory**, which consists of sensory nerve cells and their fibers.
(c) **Germinal**, which consists of those cells having especial growth or reproductive ability.
(d) **Protective**, which goes to make up an outer covering of an organ or of the body itself.

According to the structure of the composing cells, epithelial tissue is known as:

(a) **Cuboidal,**
(b) **Cylindrical,**
(c) **Columnar,**
(d) **Squamos,**
(e) **Stratified.**

Connective Tissue is known as:

(a) **Cellular,** when it is composed almost entirely of cells with little substance in between them.
(b) **Homogeneous,** if the entire substance looks very much alike.
(c) **Fibrous,**
(d) **Cartilage,**
(e) **Bone.**

The **Muscular Tissue** is divided into:

(a) **Striated or Voluntary Muscles,**
(b) **Non-striated or Involuntary Muscles,**
(c) **Heart Muscle.**

The **Nervous Tissue** consists of cells known as:

(a) **Unipolar,**
(b) **Bipolar,**
(c) **Multipolar.**

Some writers call **blood and lymph cells** (Fig. 43) a fifth type of tissue.

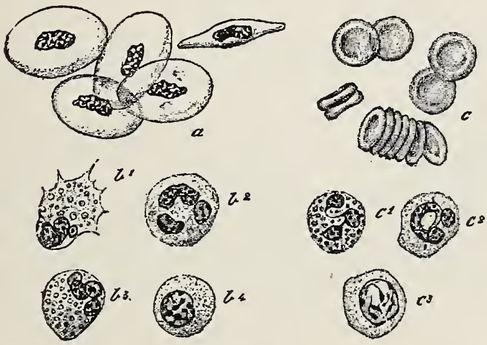


Fig. 43.

A, Red blood corpuscles (haematids) of the frog, stained with safranin and much magnified, to show the nucleus and nuclear network. *b1,* an amoeboid coarsely granular leucocyte from the frog's blood, showing trifid nucleus; *b2, b3, b4,* other forms of leucocyte from the frog's blood. c, discoid non-nucleated haematids from human blood, much magnified; *c1, c2, c3,* different forms of leucocytes from human blood. (After Bourne.)

Red Corpuscles (erythrocytes) ( ) (causing the characteristic red color of the blood) occur almost only in vertebrates. (In invertebrates, such as the earthworm, the **blood-plasma** is red.) The red corpuscle has **no nucleus in the mammal while in other vertebrates it has.**

White Corpuscles (leucocytes) ( ) are **wandering cells in the blood and lymph,** which are **phagocytic** ( ) in their action, that is, they assist in keeping the body in health by devouring foreign substances.

The various organs of the body are responsible for the particular **size, shape,** and **function** of the animal possessing them.

There are two ways of looking at an organ:

(a) **Morphologically,** or according to its **structure** or anatomy.
(b) **Physiologically,** according to the **function** such organ may perform.

If organs of different animals are **physiologically equivalent,** that is, if they **function similarly,** they are known as **analogous** organs.

If the organs of different animals are **morphologically equivalent,** that is, if they have **developed** in a similar manner in relation to the other structures immediately surrounding them, they are called **homologous organs.**

There are **three possibilities** in comparing animals:

(a) The organs may **at the same time be homologous and analogous.**
(b) They may be **homologous but not analogous,** as for example the swim-bladder of fishes and lungs of mammals.
(c) They may be **analogous but not homologous,** as for example the gills of fishes and the lungs of mammals.

The **functions of organs** are said to be:

(a) **Vegetative** (as in plants), when they have to do principally with growth.
(b) **Animal,** referring to those functions which are absent in plants or but very **slightly developed.** In the animal kingdom they are considerably increased or are totally separate and distinct from anything the vegetable world may possess.

The **vegetative functions** are equally complete in both man and the lower animals although they may **develop quite differently** in the two groups.

Animal functions are those of motion and sensation. The work of the various **specialized sense organs,** such as the eye and ear, come under this grouping, while the work of those organs which pertain to **nutrition** and **reproduction,** which both plants and animals possess equally well, are vegetative.

Living matter has been shown to have four distinguishing characteristics:

(a) **Irritability,**
(b) **Growth by intussusception,**
(c) **Reproduction,**
(d) **Nutrition.**

When nutrition is discussed biologically, it must be thought of in its widest sense as including **not only** the **taking in of food and drink,** and the digestive process consisting largely of fermentation and the absorption of such digested food, but also as including the taking in of oxygen through the respiratory tract to cause heat and energy, and the distribution through the circulatory system of the blood. And finally, there must be included the excretory system which eliminates all that for which the body has no further use.

An **organism** was defined as **any living thing capable of leading an independent existence.**

The frog is one of the **higher organisms** made up of organs, which in turn are made up of tissues consisting of sheets of similar functioning cells.

In the frog each group of tissues has a definite work to perform; i. e., the eye **only** sees and the ear **only** hears, the bones **only** support, and the heart **only** pumps blood.

This **specialization** in the work of an organ is known as a **division of labor.**

There are hundreds of thousands of animals so small that they cannot be seen with the naked eye, many of which are composed of **only a single cell.**

As they have **only one cell** they can have no tissues and consequently no organs. But, if they are living things, they **must** possess the four characteristics which distinguish living matter.

They do have these four distinguishing characteristics. Consequently the single-celled animal is as truly a living organism as is the frog.

But, as there are no organs and no tissues, the **protoplasm in this single cell must be able to do all the different kinds of work which are done by the different organs in the frog.**

Therefore, in one sense of the word, the single-celled animal which is able to do all that a many-celled animal can do without any of that many-celled animal's organs, is much more complex and remarkable than is the so-called higher form.

And lastly, even those organisms, highest in the scale of life, begin that life with a single cell which in turn grows by a division of that cell into two, then these two become four, these four eight, and so on until complete adultship is reached.

With this summary in mind we may take up the study of the single-celled organisms.

CHAPTER IX

THE PROTOZOA

AMOEBA

JUST as the frog is easily obtainable and most frequently studied in the laboratory, so the **Amoeba** (Fig. 44), because it may be found anywhere, is one of the classic forms of **uni-cellular life** that is made use of in the laboratory. This single-celled animal has the four characteristics necessary for a living being. It is found almost **anywhere**, but **not necessarily everywhere.** In fact, unless particular arrangements are made to have the **Amoebae** ready at the time they are wished for study, the probabilities are that they will not be found where one is looking for them.

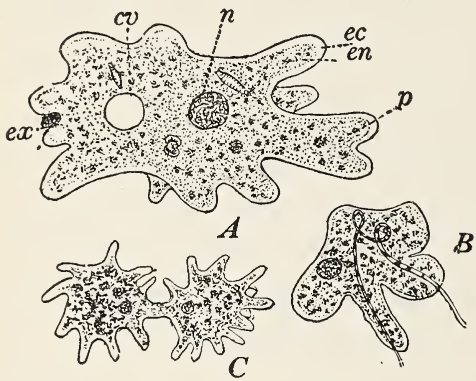


Fig. 44. *Amoeba Proteus.*

A, the animal in its natural condition; B, an animal that has ingested a long filamentous plant; C, the animal in the state of division.
cv, contractile vacuole;
ec, ectosarc;
en, endosarc;
ex, remains of undigested food;
p, protoplasm. (After Conn.)

Just as with the frog, so with a single-celled animal, we attempt first to study its anatomy or morphology. We want to ascertain what **seeable parts** go to make up this tiny animal. We find in it all the constituents of a cell and all the needed characteristics to make an organism.

There is an outer colorless layer of clear cytoplasm, called the **ectosarc** ( ), then a large central mass of **grandular cytoplasm,** known as the **endosarc** ( ). A **contractile** or **pulsating vacuole** will usually be found lying in that part of the animal **opposite the part which is moved** most frequently. There may be several **food vacuoles,** various **foreign substances** such as grains of sand, and undigested particles (these latter depending, of course, upon whether the animal is studied immediately after it has been feeding extensively). Then there is also some material which has been **digested** and is ready for **excretion,** and a **nucleus.** The nucleus is not easily distinguishable in living **Amoebae.** For this purpose animals are killed and **stained, mounted upon slides,** and studied very carefully with the **compound microscope.**

The nucleus changes with the various movements of the animal, so that it will not be found in the same location in all **Amoebae.** It has a rather **firm nuclear wall,** or membrane, and quite a number of spherical particles of **chromatin** are scattered about in the **nuclear sap.** The **contractile vacuole** usually lies near the nucleus, but as the vacuole grows it becomes further and further separated from the latter, and by the time it is ready to contract and expel its contents, lies close to the end farthest from the **pseudopodia,** at what is commonly called the **posterior end.** It then reappears close to the point of its disappearance, being carried along by the **streaming protoplasm** back to a position near the nucleus, again passing through the same stages just described.

The fluid content of the contractile vacuole is believed to contain urea. As this is the common excretory substance of animals, the vacuole is probably excretory in function. It is likely that it is also respiratory for, in all probability, CO_2 passes to the exterior of the body from the vacuole. Oxygen is taken in through the outer surface of the body. It is well to compare Amoeba's physiological functions with the respiration of a higher animal such as the frog. The food vacuoles come into existence whenever food is taken into the organism, each vacuole seemingly acting as a **temporary stomach.**

MOVEMENT

The **ectosarc,** also called **ectoplasm,** sends out **finger-like projections** into which the **cytoplasm of the cell then flows.** These outpushings are known as **pseudopods** ( ), or **rhizopods** ( ). Often several of these pseudopods are thrust out at one time, although usually the one which comes in contact with some object gains the mastery, all of the animal then moving forward so that the cytoplasm extends into the outpushing.

Various theories have been advanced to account for **Amoebae's** movements (Fig. 45), as follows:

1. **The adherence theory.** This merely means that, if a drop of water or any inorganic liquid is placed upon a flat surface, a part of it coming in contact with some other substance, the entire drop will gravitate toward the attached end. Many pseudopods extend out into the surrounding liquid, however, and do not come in contact with any other solid substance. While this theory might explain those pseudopods which **do become attached, it does not explain those which are known as free** and which do not come in contact with solid objects.

2. **The surface tension theory.** This theory is also taken from physics and chemistry and supposes that various **currents** move **forward** or outward **in the central axis** and **backward along the surface.** Unfortunately for this theory, the currents in **Amoebae** do not run that way.

3. **The contractile theory.**[1] This theory has had a varying history,

[1]It should be noted that this theory, even if true, in reality explains nothing. It simply pushes the problem back one step farther. That is, if it should prove true that Amoebae contain a contractile substance by virtue of whose properties they move, it would then be necessary to explain contractility in the substance—whence the property came, and what its actual meaning may be. In other words, we are forced back to a consideration of the fundamental physiology of the cell.

although apparently it holds the stage as well as any, and better than most theories at this particular moment. The current seems to start at the foremost part of the animal and extends backward. Jennings has shown that **Amoeba verrucosa** resembles an **elastic sac filled with fluid.** By placing this animal in a substance such as soot, which he caused to surround one of them, it was shown that the streaming followed the ectosarc toward the forepart of the animal, and just as it got beneath the **Amoeba,** remained there until the animal had moved over it, when it again moved upward at the posterior end.

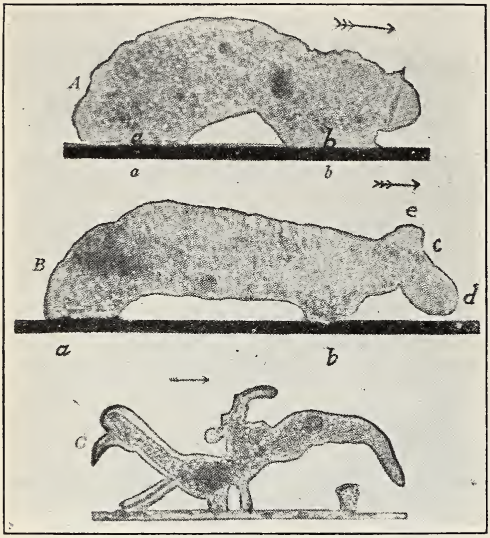


Fig. 45.—Locomotion of *Amoeba proteus.*

Photographs in side view. A and B show a specimen attached at two points, *a* and *b*, and a pseudopod which projects from one end and bends down to the substratum as in B at *d;* C shows the extension of a long pseudopod. (From Hegner after Dellinger.)

Dellinger has shown that whether on floor or ceiling, wherever **Amoebae** are found to move, there is a sort of creeping walk by which one or more outer parts of the animal are extended at random. When this projecting part comes in contact with a solid substance the most posterior attachment relinquishes its pseudopod. It is, therefore, assumed that there is a **contractile substance** within the animal.

All the various experiments along this line have depended upon **surface tension** for their explanation. However, **even if the animal moves in a similar manner to a drop of liquid that is not living, it does not follow that the same force in each case causes the movement.**

It is essential that all of the subject headings under which the frog was studied should also be borne in mind when the single-celled animals come in for investigation. For example, in regard to **metabolism,** the following subjects must be studied just as in a more complex organism: **Ingestion, digestion, egestion, absorption, circulation, assimilation, dissimilation, secretion, excretion,** and **respiration.**

It can readily be understood that there must be some **instinctive** process by which **Amoebae** know what food to ingest and what not to, or they might continue to take in sand particles and indigestible substances which would cause the body to become so extended and heavy that the animal would die from this effect alone. There are, of course, no organs such as a mouth and intestinal tract, as in the frog. The food is taken in **at any point** of the body. This food consists of tiny aquatic plants, other single-celled animals, bacteria, and various types of animal and vegetable matter.

It is of special interest to note that when food is taken by **Amoeba** the animal really places its body **around the food** (Fig. 46). Experiments with **inorganic substances**, such as a drop of chloroform in a watch glass of water, have shown that the chloroform will take in substances like shellac and paraffine and reject wood, glass, etc. It must not be forgotten, however, that these substances, which are thus accepted by the inorganic drop of liquid, are those which **normally adhere to chloroform.** But with **Amoebae** the majority of food substances **do not adhere** to the surface of the animal, and so again there is considerable dissimilarity between the experiment and the actual facts in the case.

In digestion, the food vacuoles have been embedded in the endoplasm. The vacuole wall secretes a fluid containing some mineral acid, supposedly HCl. This digestive fluid seems to dissolve only proteid substances, and has no effects upon fats and carbohydrates. Hofer performed an interesting experiment by cutting an **Amoeba** in two parts after it had just been well fed, and the part that did not have the nucleus was unable to digest food.

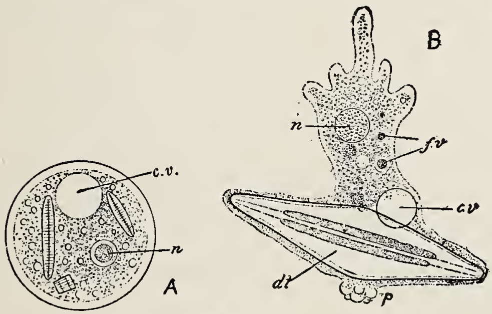


Fig. 46.

A, Amoeba encysted.
B, Amoeba ingesting a plant. *p*, retracted pseudopodium; *dt*, plant (diatom) taken in as food. *cv*, contractile vacuole; *f.v.*, food vacuole; *n*, nucleus. (After Leidy and Howes.)

A somewhat similar condition will be found a little later in the study of the **earthworm.** If the earthworm is cut in two behind certain segments, the forepart of the animal, which contains the important organs, will **regenerate** a new tail, whereas the tail-part, which has been cut off, will **regenerate** another tail. Such an animal has no mouth and must consequently starve to death as it has no way of ingesting food.

After digestion has taken place in **Amoeba,** any indigestible particle may be thrown out at almost any point on the surface of the animal. These indigestible substances are probably heavier than the protoplasm itself, so that this heavy portion sinks through the lower part of the animal's body. Then, as the animal moves away, it leaves the indigestible solid particle behind.

There is **no circulatory system proper** in a one-celled animal, so that after the food has been digested, it must be absorbed and passed into the body substance proper of the animal. Here we come to a new term, that of **assimilation,** which means that now that new food matter has been digested and is within the body, there must be a rearrangement of some kind to form new particles and to add them to those already existing. It is this ability to **manufacture protoplasm from unorganized matter that is one of the very fundamental properties of living matter.**

Any movement, or energy, expended by an animal is due to the **breaking down of complex molecules** by what is known as **oxidation.**[1] The process of tearing down is called **katabolism** or **dissimilation.** This is a slow **combustion process** giving out heat and producing energy by which the animal can perform its various functions of life. The substance thus broken down and "used up" must also be accounted for in any scientific study. This **residual matter** usually consists of solids and fluids; namely, **water** and some **mineral substance, urea** and **carbon dioxide** (CO_2). Under this heading we include all **secretions, excretions,** and **products of respiration.**

Whenever glands produce a substance which is to be used again by the animal, such product is called a **secretion,** while substances which are thrown **out of the body** entirely, are called **excretions.**

The **contractile vacuole,** since it probably contains uric acid, is considered an **excretory organ,** and because CO_2 also makes its way to the exterior of the organ, it is supposed to be **respiratory** likewise. **Amoeba,** like any animal, grows more rapidly than otherwise, if food is plentiful. Since food **is** taken internally, the growth comes from the center **outward;** in other words, by **intussusception.**

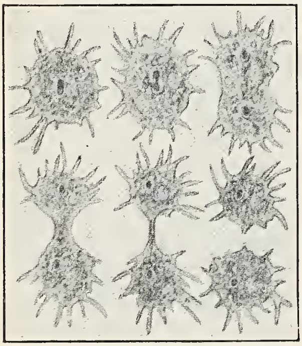


Fig. 47.

So-called amitotic division of Amoeba, showing the changes which take place during division. The dark body in each figure is the nucleus; the transparent circle, the contractile vacuole; the outer, clear portion of the body, the ectoplasm; the granular portion, the endoplasm; the granular masses, **food** vacuoles. Much magnified.

Whenever a cell reaches its full growth, its outer shell, membrane, or whatever its external covering may be called, not having infinite possibilities in the way of extension and stretching, usually breaks if more food is taken. **Cell division** is the process by which the plant or animal starts anew, thus saving **the parent cell** from breaking. A simple division into two (Fig. 47) is called **binary** division. It will be remembered that this mere splitting in two parts is the shortest method by which cells divide, but, which, as we have already said, probably does not occur at all. It is, therefore, only because our observational methods are not sufficiently delicate to note the **exact processes,** that we speak of amitotic division at all. **In Amoeba proteus,** however, which we are studying, there are two methods of division: The so-called **simple binary** or **amitotic,** just mentioned, and a process known as **sporulation.** A few instances have been reported

[1]Oxidation may be likened to a series of infinitesimal explosions which could be detected if we had instruments delicate enough for such a purpose.

where the animal formed definite mitotic figures. Very few investigators have observed **sporulation**, but where it was observed the process lasted from two and one-half to three months. The pseudopodia were first drawn in, and the animal became spherical. A three-layered **cyst** was then **secreted** within which the **Amoeba** rotated for several days. Then all movement ceased. The **nucleus divided** until there were twenty or thirty nuclei present, all arranged near the surface. This division of nuclei continued until there were from five hundred to six hundred. Walls then appeared at the periphery, cutting off each nucleus with a small amount of cytoplasm. The wall of the cyst became soft and was broken to allow the small **Amoeba** to escape. Hundreds of these amoebulae, or **pseudo-podiospores** as they are sometimes called, broke out at one time to become recognizable as **Amoeba proteus** in from two and one-half to three weeks. No reason for such sporulation is known. Experiments have been made in which specimens were starved, given an excess of food, allowed to dessicate, or where they were transferred to water from different localities, but none of these experiments brought about encystment and sporulation.

Whichever way the animal may divide it is simply a matter of growth before it is ready to divide again. We have here the interesting fact confronting us that these little single-celled animals are practically **immortal.** That is, **they do not die.** One may kill them by boiling and in other ways; but, left to themselves, they will continue until they have reached their limit of adultship when they divide, each individual becoming two new and separate animals.

It is important that the fact be grasped that in these little unicellular animals a parent **does not give birth** to its offspring. The **parent itself becomes the offspring.** That is, **there are no ancestors.** Each and every animal carries its complete and total ancestry with it.[1]

BEHAVIOR

The way in which an animal reacts to a stimulus is called its **behavior**; and when that behavior has **not been learned**, but comes forth without consciousness on the part of the animal, yet is protective to the animal, such behavior or reaction is called **instinct**. In these lower one-celled animals two words are used in discussing behavior and instincts. These are **tropisms** or **taxis**,[2] which merely mean a **movement of some kind.** To these words one adds the generic name of the stimulating cause, using the words **positive** and **negative** to explain one's meaning. For example, usually **eight tropisms** or **taxis** are mentioned:

(1) **Thigmotropism,** meaning a **reaction to contact** of some kind;
(2) **Chemotropism,** meaning a **reaction to a chemical**;
(3) **Thermotropism,** meaning a **reaction to heat**;

[1]An apparent exception to this statement arises if we accept, as a fact, that conjugation in the Infusoria is fundamentally a rejuvenation phenomenon as some biologists contend. Even if this be true, still there is nothing extra added, and the statement remains substantially correct.

[2]In a strict sense "tropisms" mean the growing or bending of an organism, or parts of an organism, in relation to external agents, while "taxis" refer to the active migration of organisms or cells. However, most modern writers are inclined to use these terms interchangeably.

(4) **Phototropism,** meaning a **reaction to light;**
(5) **Electrotropism,** meaning a **reaction to an electric current;**
(6) **Geotropism,** a **reaction to gravity;**
(7) **Chromotropism,** a **reaction to color;**
(8) **Rheotropism,** a **reaction to current.**

Amoebae move away from strong light, so that they are said to be **negatively phototropic.** They are also **negatively thigmotropic.**

If an action is self-imposed, it is said to be **autogenous** ( ); if an external object causes a reaction, whether such object be located within or without the body, the action is known as **etiogenous** ( ).

EUGLENA

This little organism (Fig. 48) moves about like a full-fledged animal although it has chlorophyl in its body and manufactures its food as does the plant; and it does this notwithstanding the fact that it has a mouth and gullet.

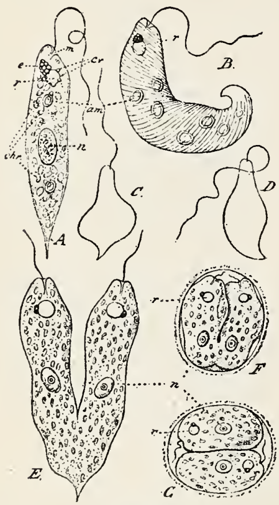


Fig. 48.

A. *Euglena viridis; m,* the so-called mouth; *n,* the nucleus; *e,* the stigma; *r,* reservoir; *c.v.,* contractile vacuoles; *chr,* chromatophors; *am,* pyrenoids with sheaths of paramylum. B, another specimen, showing change of shape and diagonal striation of the cuticle. C and D, outlines to show various stages of contraction. E, a free swimming specimen undergoing longitudinal division. F and G, division of an encysted form. (A-D, after Bourne; E-G, after Stein.)

Euglena belongs to the **Class Mastigophora** ( ), which means that there is a **whip-like flagellum** protruding from its **anterior end.** Several animals must be grouped together in order that the naked eye may see any organisms present. When there are many in one place a characteristic green color is given the surrounding water.

EXTERNAL AND INTERNAL FEATURES

Euglena viridis is a single celled, elongated animal pointed at the posterior, and blunt at the anterior end. As in **Amoeba,** there are two layers in the cytoplasm, the **ectosarc,** a dense outer layer, and the **endosarc,** a more fluid central mass. There is a thin **cuticle** running in parallel thickenings around the body of the animal in an oblique direction so that it appears striated.

The **mouth** is a funnel-shaped depression lying a little to one side of the center of the anterior blunt end. The **gullet** is a continuation of this depression. It looks like a duct, and connects with a large **spherical**

vesicle, the **reservoir,** into which several minute **contractile vacuoles** discharge their contents.

There is also a red dot, called an **eye-spot** or **stigma,** close to the reservoir, near the inner end of the gullet. It is made up of small granules of **haematochrome** ( ). Because the anterior end of the animal seems to be more sensitive to light than other parts, it is supposed that this red stigma functions somewhat as an eye. It has been suggested that this red haematochrome is not the sensitive part at all, but that the protoplasm immediately beneath it is sensitive. As haematochrome has many of the characteristics of pigment granules of the eyes of higher animals, it is likely that we meet here with a sort of **beginning eye.**

There is a **single nucleus** a little posterior to the center of the body. It has a **distinct membrane.** On the inside of the nucleus there is a **so-called nucleolus.** However, as this latter functions as a **division center,** it is probably not a nucleolus.

There are a number of oval discs called **chromatophores** ( ) suspended in the protoplasm. These contain **chlorophyl.** In **Euglena** we meet with our first example of **photosynthesis** ( ). A little later, when plant-life is studied, it will be noted that this is the accepted method among plants of manufacturing their food. Photosynthesis means that the chlorophyl is able, **in the presence of light,** to break down the carbonic acid (CO_2), and set free the oxygen to unite the carbon with water, thus forming a substance allied to starch called **paramylum** ( ). If specimens are kept in good light continually, a large amount of paramylum will be stored up for future use. This is laid down around some granules of proteid substance near the center of the body. These granules are called **pyrenoids** ( ). The pyrenoids and the chromatophores are permanent cell structures. They increase in number by division and not by the origin of new ones from other parts of the body.

LOCOMOTION

The animal moves by means of its **flagellum,** which appears as a single whip-like structure, although really it is composed of four separate fibrils wound together. This flagellum begins in the body proper and extends through the wall of the mouth depression. It is often as long as the animal itself. In addition to the assistance rendered the animal in locomotion by this appendage, the entire animal is elastic, contracting and expanding, so that the body looks much like a worm in movement.

NUTRITION

As already stated, **Euglena** is like a plant in that it possesses chlorophyl and manufactures its own food. When an animal manufactures its food in this way it is said to be **holophytic** ( ). But as **Euglena** can live in the dark, and chlorophyl does not permit the manufacture of food without light, the animal must be able to feed also in some other way. When organic substance in solution is taken in through the body wall, as probably happens in the case of **Euglena** in the dark, such method of obtaining food is said to be **saprophytic** ( ), while those animals which ingest **solid particles of food** like the frog are said to be **holozoic** ( ).

ENCYSTMENT

Euglena, like **Amoeba,** when food becomes scarce, as well as for unknown reasons, may encyst. It does this by becoming spherical, secreting a rather thick gelatinous covering, and throwing off the flagellum.

REPRODUCTION

This takes place by **binary longitudinal division.** The nucleus is divided by a primitive sort of mitosis. The body begins to divide at the anterior end. The old flagellum is retained by one-half of the body, while a new flagellum is developed by the other half. Division often takes place while the animals are in an encysted condition. One cyst usually produces two **Euglenae,** although these may divide while still within the old cyst wall so as to make four in all. Recent observers have recorded as many as thirty-one young, flagellated **Euglenae** which escaped from a single cyst.

BEHAVIOR

Euglena swims in a spiral manner as does **Paramoecium.** Like **Paramoecium,** too, it has only two reactions to the stimuli of touch. But in the case of **Euglena,** the forepart of the animal swings about in a circle while the posterior part remains more or less stationary, thus forming a sort of pivot around which the forepart moves.

Euglena is **positively phototropic,** but direct sunlight will kill it. All plants and animals thrive in certain quantities of oxygen, moisture, and heat, but are injuriously affected if too much of these is applied. This explains phototropic action as well as the killing by an over-abundance of light. The environmental condition in which an organism thrives best, is called the **optimum** ( ) for such organism.

VOLVOX

All unicellular animals which have whip-like flagella, come under a sub-grouping known as **Mastigophora.** This group is particularly interesting in that it furnishes us with our first example of unicellular animals forming **colonies.** The best known and studied of this group of **colonial flagellata** is **Volvox** (Fig. 49) found in fresh water ponds. Doflein found as many as 22,000 cells in a single colony. There is a **division of labor** in the colonies, for the various cells are not all alike, though each is a separate and distinct animal. Some of these cells are **somatic** and nutritive, while others are **germ-cells** or reproductive cells. Here we come in contact with the lowest form of **sex life**. Any organ which produces sex cells is known as a **gonad.** There are certain germ cells in a colony of Volvox called **parthenogonadia** ( ). These divide into many cells which drop into the center of the mother colony and finally escape through a break in the wall. There are **other** germ cells, however, which are also produced; the smaller are called **spermatozoa** or **microgametes.** These are the **male germ cells,** while the **larger ones, called macrogametes** or **eggs,** are the **female germ cells.** The **eggs are fertilized** by the spermatozoa, and, after passing through a **resting stage,** develop into new colonies.

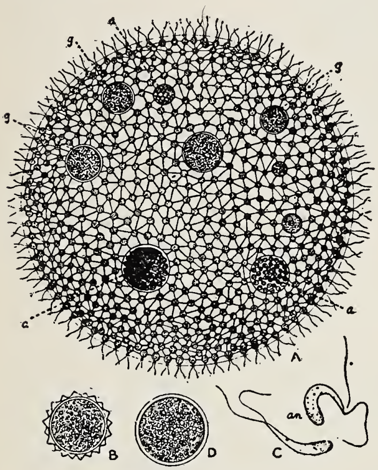


Fig. 49. Volvox.

The individual cells are united by radiating strands of protoplasm. A, a mature colony; *a*, spermaries; *g*, ovaries. B, zygote resulting from the fusion of the gametes. C, two sperm. D, egg. (From West, after Klein.)

Colonies may be of one sex only. In such cases the male colonies can be recognized by the sperm pockets arranged in a wide belt around the middle of the colony with the poles free from cells.

There is a distinct difference between a colony of single-celled animals of this kind and a **tissue.** A tissue is a sheet of similar functioning cells, such sheet being combined with others to form an organ, while the organs, taken together, form a complete single individual. In **Volvox** there is no such grouping of sheets of similar functioning cells. **Each cell is complete and distinct in itself** and is as much an individual as **Amoeba** or **Euglena** just studied, except that it is attached to its fellows.

PLASMODIUM MALARIAE

The malarial organism, **Plasmodium malariae** (Fig. 50), a member of the class **Sporozoa,** nearly all of which are parasitic, lives in the human body. Human blood contains minute circular disks, known as red blood corpuscles, within which the malarial organisms may be found in persons who are suffering from **malaria,** or **chills and fever.** The organism first appears as an extremely minute body, in shape somewhat like the **Amoeba,** though much smaller. It increases in size. After reaching a size which nearly fills up the red blood corpuscles, it breaks up into twelve to sixteen small spores. The blood corpuscles now break into pieces and the spores are liberated into the liquid blood. Each may then make its way into a corpuscle and repeat again the history just described.

All of the following details of the life-cycle of **Plasmodium malariae** must be thoroughly understood and memorized by the student, because,

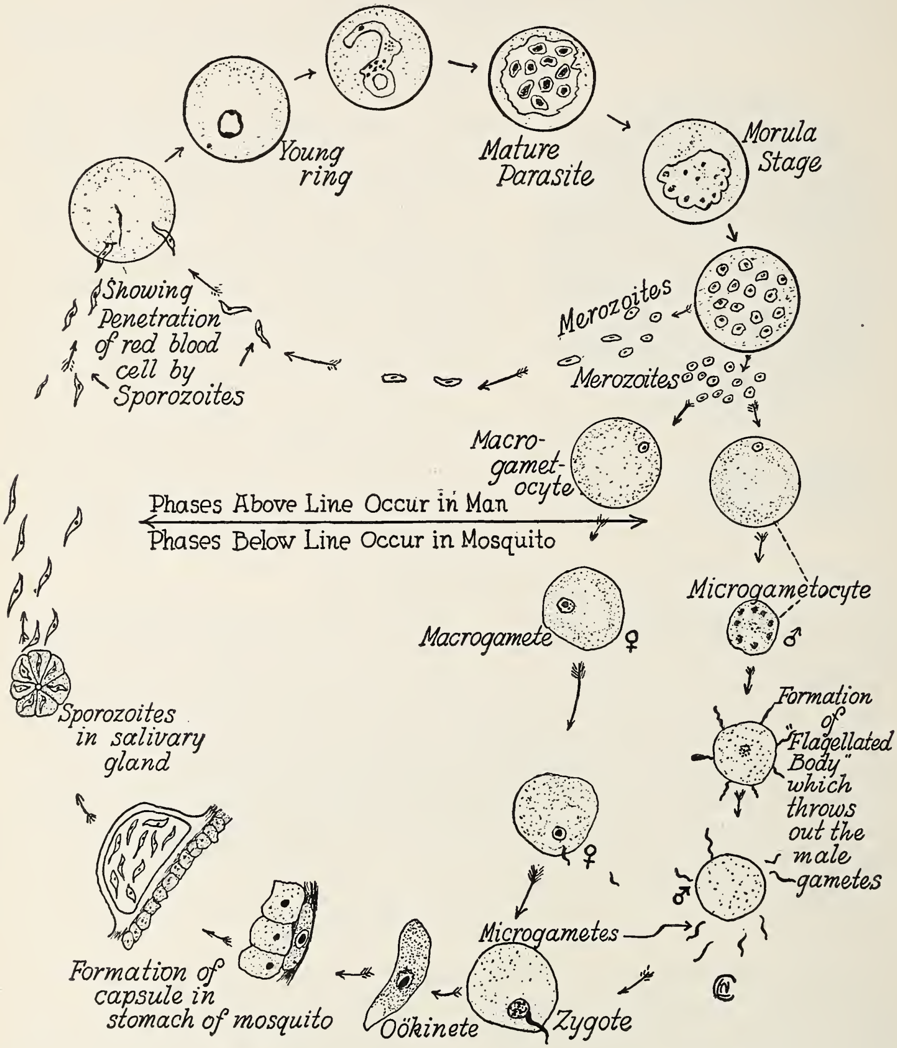


Fig. 50. Life Cycle of Plasmodium Malariae.

(1) **Plasmodium malariae** is the classic example of an animal-parasite of tremendous importance to man; (2) it is our best known example of a parasite which requires an **intermediate host** before being able to carry infection; (3) it presents an excellent illustration of the methods

used in obtaining experimental proof for scientific theories; and (4) it brings home an understanding of the vast quantity of painstaking effort necessary to obtain that proof.

The malarial organism, **Plasmodium malariae,** is a member of the class **Sporozoa,** nearly all of which are parasitic. It lives in the red corpuscles (therefore called **Haematozoa**) of human blood where it grows for a time, and then breaks up into from twelve to sixteen spores which rupture the corpuscle. The corpuscle itself then breaks up into tiny particles and the spores are thrown into the blood-stream.

The malarial parasite has two **life-cycles** (Fig. 50), so to speak, one the **sexual cycle,** which develops in mosquitoes, and the other the **asexual cycle,** which develops in man.

1. The **sexual development** of the malarial parasite within the body of the mosquito takes from eight to ten days. These sexual forms are known as **gametes.**

The male cell **(gamete)** is also called a **gametocyte.** This gametocyte develops from four to eight **microgametes** which force their way into the large female cells **(macrogametes).**

A sort of fertilization is thus set up. This fertilized cell is now called a **migrating cell** or **oökinete.** The oökinete penetrates the stomach-wall of a mosquito and builds a cyst **(oöcyst).** Grassi says that there may be as many as five hundred oöcysts at a time in the stomach-wall of a single mosquito.

In the oöcyst many tiny spherical bodies develop (**sporulation**). These spherical bodies are the **sporoblasts** (primitive spore-cells) which develop into thousands of **sporozoites.** These latter are merely tiny filaments which get into the lymph system of the entire body of the mosquito. As they reach the mouth-parts, they are ready to be injected into any human being which the mosquito bites. Once inside man, they enter the red-blood corpuscles and are known as **schizonts** (asexual forms).

From here on we must trace the asexual cycle of development in man. The injected organism which has been placed in the blood-stream of man is called a **sporozoite.** It finds its way into the red blood corpuscles and becomes rounded and more or less ring-shaped, while it is amoeboid in movement. It is now a full-fledged **schizont** ( ). The schizont lives at the expense of the red corpuscle and deposits scattered black or reddish, so-called **melanin** granules. These granules should properly be called **haematozoin granules** ( ).

The schizont now matures and becomes rosette-shaped when it is known as the **morula.** Its nucleus breaks into daughter nuclei, or rounded spores, known as **merozoites** ( ), the number of which may vary from six (in the Quartan fever parasite), to twenty (in the Tertian fever type).

The red corpuscle is finally broken up. This liberates the merozoites into the blood-stream where (within an hour) they may again attack and enter other red blood cells.

The breaking up of the red blood cells takes place at the moment the merozoite is mature, and the chills and fever likewise appear at this time.

It will be readily understood that, when thousands of red corpuscles are thus removed from the circulation, the patient will be pale **(anaemic)**. The chills may be due to the haematozoin granules, which possibly contain poisonous substances.

This process of the merozoites being thrown out of the red corpuscles into the blood stream may continue for some time, but after a while, rounded forms, which throw off tiny filaments, appear. These are the male sexual forms, while the larger macrogametes are the female forms. Both male and female forms, however, require a mosquito as host before being able to develop further. The sexual cycle, already described in the mosquito's body, now begins, if the infected individual is bitten by a female **Anopheles** mosquito.

The chills always appear at regular intervals, because the **incubation period** of each of the three kinds of malarial parasites (although differing for each species) is always the same for the same species. Thus the tertian fever species **(Plasmodium vivax)** "hatches" every third day—hence its name; the quartan **(Plasmodium malariae)** every fourth day while the aestivo-autumnal type **(Plasmodium immaculatum Laverania)** at irregular intervals. In fact, the physician uses this definite incubation period as his clue in diagnosing the case, to find what particular type of malarial parasite has infected his patient.

After the spores or merozoites are thrown into the blood-stream, many are devoured by the white corpuscles **(leukocytes)**, but those not devoured, again enter new red corpuscles and so continue reinfecting the same patient, although they are unable to infect another.

The method of **communication** from one person to another can only come about in the following manner:

A female mosquito of the genus **Anopheles** must suck the blood of an infected person if the disease is to be communicated. As soon as the infected blood reaches the changed environment of the mosquito's stomach, the series of changes begins in the merozoites, which have been described above. It will thus be seen that **Plasmodium malariae** must not only pass through two stages of a life-cycle, **sexual** and **asexual**, but these two stages are unable to develop in a single host, the asexual stage developing in man, and the sexual in mosquitoes.

At this point the question will occur, "How do we know all this?" It is the answer to this question which will give the student (1) the finest illustration of what modern laboratory methods mean; (2) it will acquaint him with the exhaustive investigations which students of science are always performing, and (3) it will show him what great quantities of material must be sifted before one can prove an accepted scientific theory, or advance a new one.

It was on November 6, 1880, that Dr. Laveran, a French army surgeon serving in Algeria, plainly saw the living parasites under the microscope in the blood of a malarial patient. But it was not until five years later that medical men accepted his findings. Then several Italian pathologists, prominent among them being Golgi, Marchiafava, and Celli, worked out the behavior of the parasite in human blood. These men found that the fever and chills always came at definite periods of development in the parasite.

But they could not find how the parasite got into the blood of the patient. The name "Malaria" is Italian and means "bad air" (malaria). As the disease had always been associated with swamps and stagnant water, it is not strange that mosquitoes had been thought of as having some relationship to the disease. Medical men were, however, inclined to consider such a thought as savoring too much of superstition to accept it.

Notwithstanding this general attitude, Dr. A. F. A. King, an American physician, in 1883 summed up the evidence which to him seemed quite conclusive for such an association.

Riley and Johannsen have put Dr. King's argument in the following words:

"1. Malaria, like mosquitoes, affects by preference low and moist localities, such as swamps, fens, jungles, marshes, etc.

"2. Malaria is hardly ever developed at a lower temperature than sixty degrees Fahr., and such a temperature is necessary for the development of the mosquito.

"3. Mosquitoes, like malaria, may both accumulate in and be obstructed by forests lying in the course of winds blowing from malarious localities.

"4. By atmospheric currents malaria and mosquitoes are alike capable of being transported for considerable distances.

"5. Malaria may be developed in previously healthy places by turning up the soil, as in making excavations for the foundation of houses, tracks for railroads, and beds for canals, because these operations afford breeding places for mosquitoes.

"6. In proportion as countries, previously malarious, are cleaned up and thickly settled, periodical fevers disappear, because swamps and pools are drained so that the mosquito cannot readily find a place suitable to deposit her eggs.

"7. Malaria is most dangerous when the sun is down and the danger of exposure after sunset is greatly increased by the person exposed sleeping in the night air. Both facts are readily explicable by the mosquito malaria theory.

"8. In malarial districts the use of fire, both indoors and to those who sleep out, affords a comparative security against malaria, because of the destruction of mosquitoes.

"9. It is claimed that the air of cities in some way renders the poison innocuous, for, though a malarial disease may be raging outside, it does not penetrate far into the interior (of cities). We may easily conceive that mosquitoes, while invading cities during their nocturnal pilgrimages, will be so far arrested by walls and houses, as well as attracted by lights in the suburbs, that many of them will in this way be prevented from penetrating far into the interior.

"10. Malarial diseases and likewise mosquitoes are most prevalent toward the latter part of the summer and in the autumn.

"11. Various writers have maintained that malaria is arrested by canvas curtains, gauze veils and mosquito nets, and have recommended the use of mosquito curtains, through which malaria can seldom or never pass. It can hardly be conceived that these intercept marsh-air but they certainly do protect from mosquitoes.

"12. Malaria spares no age, but it affects infants much less frequently than adults, because young infants are usually carefully housed and protected from mosquito inoculation."

King's work does not seem to have come under the notice of the European and Asiatic workers, so it was not until 1894 that Sir Patrick Manson, who had done pioneer work in filariasis (See Chapter XX), came to the conclusion that there must be an intermediate host for a parasite so similar in its general functioning as malaria is to filaria.

It was already known that long thread-like processes formed as soon as the parasite escaped from the blood, and became free-swimming in the surrounding media.

At first it was thought that water containing the parasite was the carrier of infection, but no persons who drank the water developed malaria; in fact, they did not even develop the disease when this water was actually injected into the veins.

Manson then suggested that these motile forms must have something to do with the manner of communicating the disease, and it was he who also thought a blood-sucking insect the most likely intermediate host. After so much progress had been made, it was a simple matter to think of the old association of mosquitoes and malaria.

It is interesting to note also, that Laveran working independently, came to similar conclusions in the same year that Manson did.

Major Ronald Ross, in India, without any knowledge of the form or appearance of the parasite during the time it is developing within its intermediate host, and without a knowledge of the species of the insect he was looking for, spent two and a half years of intensely arduous work following out experiments largely suggested by Manson.

Finally, in August, 1897, seventeen years after the parasite was first discovered in man, he obtained his first clue.

While he was dissecting a "dappled-winged" mosquito and had searched every cell and found nothing, he came to the insect's stomach. In writing of this, Major Ross says: "Here, however, just as I was about to abandon the examination, I saw a very delicate circular cell, apparently lying among the ordinary cells of the organ and scarcely distinguishable from them. On looking further, another and another similar object presented itself. I now focused the lens carefully on one of these, and found that it contained a few minute granules of some black substance, exactly like the pigment of the parasite of malaria. I counted altogether twelve of these cells in the insect."

As he searched further he found that the mature pigment cells contained multitudes of thread-like bodies which, when the parent cell was ruptured, poured into the body of the insect. These were the spores formed in the sexual generation.

Major Ross did his experimental work on birds which are infected with malaria, but his results were soon found to apply to man as well.

So complicated a scheme of things can never appeal to men at large, and yet it is just men at large who must assist in any preventive measures which are to wipe out diseases of this nature. For this reason a series of popular experiments was made.

Drs. Sambon and Low, of the London School of Tropical Medicine, went to the most malarial portion of Rome in the most dangerous season. They lived with three or four others from July until the 19th of October in a specially constructed mosquito-proof hut near Ostia. They were thus protected from sunset to sunrise from the bites of mosquitoes. Not one of them became infected, while mosquitoes sent from here to London were allowed to bite several people (Dr. Manson's own son being one of the subjects who volunteered for the experiment), all of whom came down with the diseases.

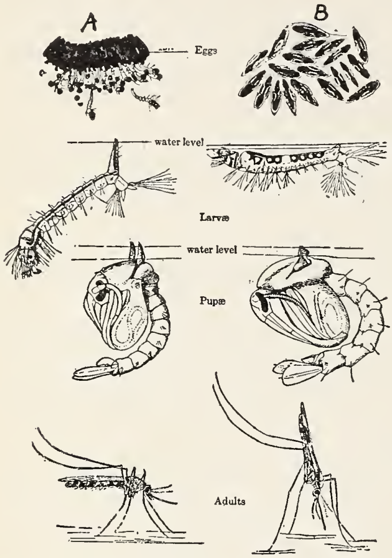
Again, in Italy, railroad employees who were housed in mosquito-proof huts did not develop the disease while those not so housed did.

Our own experiences in cleaning up the Panama Canal Zone of malaria and yellow fever are notable examples of preventive measures used most effectively, from the knowledge gained in the study of the life-cycle of the malarial parasite.

In Cuba, yellow fever (also a disease caused by an infecting parasite carried by the mosquito), was shown, likewise, to be carried only through an intermediate host. Major Walter Reed had workmen sleep in beds and use the clothing of those who died of yellow fever, but kept such men housed in mosquito-proof huts. Not one developed the disease, while those who were bitten by the infecting mosquito and having perfectly clean bedding and linen took the disease. Dr. Charles J. Finlay of Havana, Cuba, and Major Walter Reed are the Manson and Ross of the yellow-fever parasite.

There are 125 species of mosquitoes in North America, but it is only the female of the genus **Anopheles** which can transmit malaria to man, though some members of the genus **Culex** do transmit it to birds. (At least this is true in India.)

The distinguishing characteristics of the two groups is as follows (Fig. 51): In **Culex** the wings are clear, while in **Anopheles** they have



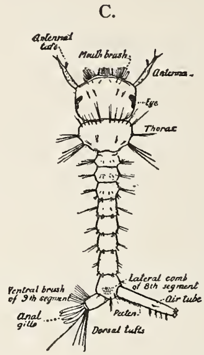


Fig. 51.

A.—Life history of house mosquito (Culex).
B.—Life history of malaria mosquito (Anopheles). (From Howard, U. S. Dept. of Agriculture.)
C.—Culex larva, showing details of external structure. (After Riley and Johannsen.)

brown spots. In **Culex** the axis of the body forms a curved line as though the insect were hump-backed, while **Anopheles** presents a straight line when resting. For those familiar with insect anatomy we may add that **Culex** has short maxillary palpi while **Anopheles** has them almost as long as its proboscis; and lastly, for those with a musical ear, we may add that the female **Anopheles,** which is the only one which carries the malarial parasite, sings several tones lower than the **Culex.**

The eggs of **Culex** are always laid in a mass, while those of **Anopheles** are laid singly. As the eggs hatch, the larvae of **Culex** hang from the surface of the water at about an angle of 45 degrees, while the larvae of **Anopheles** lie almost parallel to the surface of the water.

Prevention is always the scientific method of overcoming disease. Because mosquitoes lay their eggs in quiet pools, men conceived the idea of preventing these eggs from hatching. Such prevention of hatching has not been possible, but oil poured on the water kills the little wrigglers after they have hatched.

The breathing tubes of wrigglers are provided at their openings with **hydrofuge plates** which will not permit water to enter. Since these hydrofuge surfaces are due to the presence of oil, it is obvious that oil poured on the surface of the water will mix with this and cause the entry of oil into the breathing tubes, thus asphyxiating the wrigglers. It has been thought that certain kinds of fish destroy eggs and wrigglers.

Muttkowski examined over 6,000 fish stomachs and found only one mosquito wriggler. Another observer examined about 2,000 specimens of **gambusia,** the so-called "mosquito-destroying top minnow," and found mosquito wrigglers in only about two per cent of the fish.

PARAMOECIUM

The animal now to be studied is the **Paramoecium** (Fig. 52), a member of the **class Infusoria.**[1] Paramoecia are often called slipper animalculae because they are shaped like a slipper, or more correctly like a cigar. The **distinctive characteristic** of this animal is that its entire body is covered with **little hair-like projections,** called **cilia.** The rapid movement back and forth of these cilia (especially those of the oral groove which beat faster than those on other parts of the body), causes the animal to be propelled through water. An **oral groove** extends **obliquely backward** from the forward end and empties just a little behind the middle portion of the body. The mouth is situated at the end of the oral groove, so that as the animal swims and constantly revolves, various substances are forced down this groove, and, as they reach the end of the groove, are thrust into the mouth proper. It also has an endosarc and ectosarc like in **Amoeba,** and an additional membrane or **pellicle,** sometimes called the **cuticle.** This is demonstrated by placing a drop or two of 35 per cent alcohol in a drop of water where some of the **Paramoecia** are found. The pellicle will raise like a blister, showing that this part is separate and distinct from the rest of the animal. Immediately beneath the cuticle is a layer of spindle-shaped cavities in the ectoplasm. These cavities are filled with a semifluid substance. They are known as **trichocysts** (   ), supposed to be weapons of offense and defense (Fig. 53). If a little acetic acid, or ordinary blue or green fountain-pen ink, is added to the water, these trichocysts explode, and the long threads which they contain are discharged.

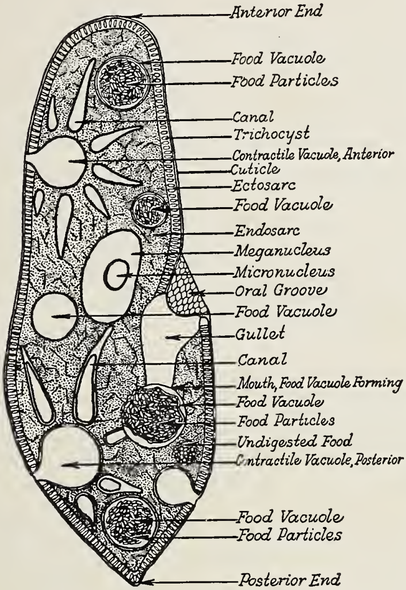


Fig. 52. *Paramoecium caudatum.* (After Bütschli.)

There are two **contractile vacuoles,** one close to each end of the

[1]The early workers in biology took vegetable matter, such as dried grass, steeped it in boiling water, and then left this infusion stand in the air. The animals found therein were called *Infusoria.*

body, while six to ten radiating canals communicate with these vacuoles and other portions of the body. These canals collect the fluid from the surrounding protoplasm and pour it into the vacuoles, after which the **vacuoles contract alternatively** at intervals of about twenty seconds at ordinary temperature and discharge their contents to the outside of the body.

This is as it is in **Amoeba,** where the contractile vacuoles act as organs of both excretion and respiration. **Paramoecia** feed on **bacteria** and certain other types of **unicellular organisms.** The animal moves back and forth rapidly, causing a current of water to be sent down the gullet so that various food particles are swept in. Along the gullet is a row of cilia, **fused together,** forming what is called an **undulating membrane.** As the food enters the end of the gullet, a food vacuole is produced, which, as soon as fully formed, separates from the gullet and is swept away by the **rotary streaming movement** of the endoplasm. This process is known as **cyclosis** ( ). The **digestion occurs within the food vacuole,** while the undigested particles are cast out at a definite **anal spot** which can only be seen when these particles are discharged.

Fig. 53.

Paramœcium defending itself from an attack by a Protozoon, *Didinium*. The trichysts are discharged and mechanically force the enemy away. (From Hegner, after Mast.)

BEHAVIOR

Conjugation and division of **Paramoecia** will be discussed in the following chapter. Here only the ordinary reactions of this animal will be taken up.

While **Paramoecia** normally swim by means of cilia, they can, when forced to, exhibit great elasticity and pass through very small openings. The body goes forward, turning round and round on its long axis, always **toward the left** as it is propelled forward. This results from the fact that the cilia in the oral groove grow more rapidly and effectively than elsewhere. Approximately the same effect is obtained as rowing in a boat in which the oars on one side are applied much more strongly than on the other. The animal would naturally swim in a circle if this were the only force applied, but as **it rotates** on its long axis continually, it goes forward. This produces a spiral course. The swerving, when the oral side is to the left, is to the right, and when the oral side is above, the body swerves downward. When the oral side is to the right, the body swerves to the left, etc. The swerving in any given direction is, therefore, compensated by an equal swerving in the opposite direction. The resultant is a spiral path having a straight axis.

Paramoecium responds to stimuli negatively and positively just as do other forms of unicellular animals. This animal has been particularly well studied in the laboratory as to its reactions to various stimuli, and it is interesting to note that whenever any injurious substance or stimulus is applied at its anterior end, the **cilia reverse themselves** and the animal **swims backward** for a short distance away from the object or substance causing stimulation. The forepart of the animal then swings about, using the posterior part as a pivot, and the animal again moves forward. If it again comes into an undesirable medium, the same process is repeated. As the animal backs up from an unpleasant stimulus, using its posterior end as the pivot upon which to turn, various samples of the surrounding medium are brought into the oral groove, so that, as soon as these samples of liquid no longer contain the unpleasant stimulus, the animal moves forward.

The important point to remember here is that **Paramoecium has only two reactions,** the **going forward** and the **going backward.**[1] Much erroneous interpretation may be avoided if this be remembered when the study of the **animal mind,** or **animal psychology,** is taken up later; for, no matter how many hundreds of times an animal of this kind may make an experiment, it always continues this **trial-and-error method** of going forward, bumping into something that is antagonistic to itself, backing up, and again coming forward until it **accidentally** gets into a medium that is satisfactory. In fact, there are some substances, such as acetic acid, to which **Paramoecia** react in a peculiar manner. If a drop of this acid be placed before the animal, it will enter the liquid; but once within the acid-drop it will react to the surrounding water in a negative manner; that is, it will come to the edge of the acid-drop and then back away again and again. Then, the **trial-and-error method** may be observed when heat is applied to the surrounding media. The animal tries almost every direction until it finds some method of escaping from the unfavorable stimulation. **The optimum temperature** is normally between 24° and 28° C.

There are positive reactions of **Paramoecium** also, such for example as its habit of lying against solid objects. **Paramoecia** are **negatively geotropic,** in that they usually come toward the upper portion of the water in which they are placed. The animals usually swim upstream, and it is supposed that the reason for this is that the current might interfere with the beating of the cilia if another direction were taken.

It is generally supposed that it is the physiological condition of **Paramoecium** which determines the character of any response to a given stimulus. This means merely that the actions are more or less **spontaneous** and **due to the internal condition of the animal (autogenous).** This internal condition changes, however, with the **different amounts and qualities of food and digestion.** One physiological state really resolves itself into another. This "becomes easier and more rapid after it has taken place a number of times," giving ground for the belief that stimuli and reaction have a distinct effect upon succeeding responses.

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[1]These two reactions are, of course, in addition to the animal's regular revolving method of locomotion.

One writer has summed up the external factors that produce or determine reactions as follows:

"1. The organisms may react to a change even though neither beneficial nor injurious.

"2. Anything that tends to interfere with the normal current of life activities produces reactions of a certain sort (negative).

"3. Any change that tends to restore or save the normal life processes may produce reactions of a different sort (positive).

"4. Changes that in themselves neither interfere with nor assist the normal stream of life processes may produce negative or positive reactions, according as they are usually followed by changes that are injurious or beneficial.

"5. Whether a given change shall produce a reaction or not often depends upon the completeness or incompleteness of the performance of the metabolic processes of the organism under the existing conditions. This makes the behavior fundamentally regulatory."

When one organism causes disease in another, it is said to be **pathogenic** to the organism affected. For example, **Amoebae bucallis** are found in **pyorrhea,** a disease of the teeth. The drug **emetine** kills **Amoebae bucallis,** and when these are killed, the diseased condition improves. From these facts it has been concluded that this particular protozoan is the cause of pyorrhea, although this is not strictly true.

While, as we shall shortly see, most of the pathogenic organisms belong to the **plant kingdom,** still the following animal organisms which cause disease in man, are rather important factors in the study of Biology:

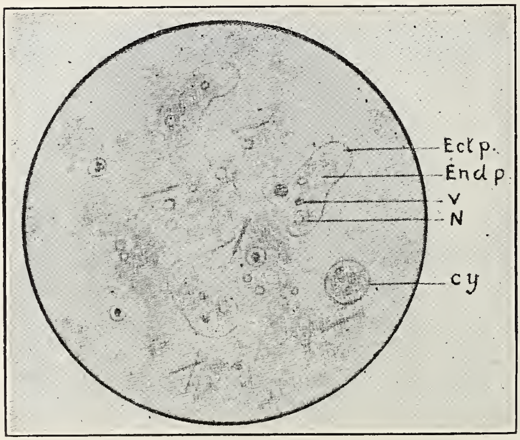


Fig. 54.

Entamoeba histolytica from a case of amoebic dysentery in man. *Ectp.,* ectoplasm; *Endp.,* endoplasm; *V,* vacuoles; *N,* nucleus. *cy,* encysted amoebae. (After Rivas.)

PATHOGENIC PROTOZOA

Class I. Rhizopoda.

(a) **Entamoeba hystolytica** (also called entamoeba dysenteriae), (Fig. 54).

Entamoeba histolytica causes a chronic ulcerative process in the large intestine, the so-called amoebic dysentery. The organisms are frequently carried to the liver by the portal circulation and give rise to abscesses which may attain large size and may extend to a pleural cavity or to a lung.

It is a common infection in the tropics, but occurs also more or less frequently in temperate zones.

The organism measures fifteen to twenty-five micra in diam-

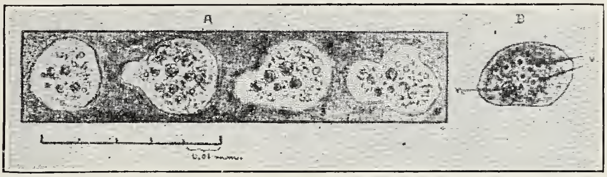


Fig. 55.

Entamoeba gingivalis (buccalis). (After A. J. Smith in Dental Cosmos, Sept., 1914.)

eter. It contains a small, round vesicular nucleus which stains but poorly with the ordinary basic dyes and with alum hematoxylin. The nucleus contains a minute nucleolus. The cytoplasm around the nucleus is finely granular and is surrounded by an outer zone or ectosarc which is transparent and refractive, and which sharply defines the outer limits of the organism.

The entamoeba hystolytica must be examined on a warm stage in order to detect the characteristic movements; but it is readily identified in properly fixed tissues owing to its characteristic morphology.

The organism is quite **phagocytic** and is frequently found to contain red blood corpuscles, bacteria, or cellular debris. It is able to penetrate fibrous and other tissues and is frequently found in the walls of blood vessels as well as within the blood vessels themselves.

It secretes a mild **toxin** (which may be a waste product). This secretion slowly kills the cells in its neighborhood and then gradually dissolves them.

Amoebae are, however, often found in normal tissues. Sometimes the nuclei seem to be fading out.

The organisms are found principally in the intestines, but sometimes also in the liver.

Cultures of these amoebae have been shown to withstand drying from eleven to fifteen months.

(b) **Entamoeba buccallis** (also called **E. gingivalis** and **E. den-**

talis) has been said to cause pyorrhea alveolaris (Fig. 55), but Rivas holds that these **Amoebae** are the effect of infection and thus represent a secondary infection which aggravates the primary infection.

Class II. Sporozoa.

Subclass 1. Telosporidia ( ).

Order 3. Haemosporidia ( ).

Plasmodium, which causes malaria. (See Fig. 50.)

Subclass 2. Neosporidia ( ).

Order 2. Sarcosporidia ( ).

Sarcocystis miescheriana. (Fig. 56.)

Medical men often call these organisms "Rainey's tubes." They are found in the muscles of pigs.

The tubes are ovoid bodies filled with small sickle-shaped unicellular organisms—the **Sarcocystis miescheri.** It sometimes is found in man, where it causes a serious disease called **psorospermiasis,** usually fatal.

Class III. Mastigophora.

Order 1. Flagellata.

Trypanosoma gambiense (Fig. 57) causes the disease known

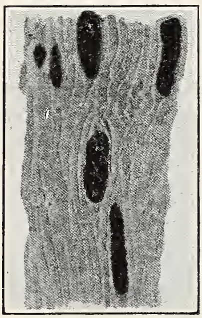


Fig. 56.

Longitudinal section through muscle of a Pig, containing *Sarcocystis Miescheriana* (From Kühn, after Braun).

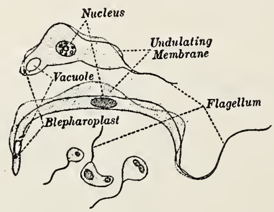


Fig. 57.

Trypanosoma gambiense, from a case of sleeping sickness. Different forms. (After Manson.)

as **trypanosomiasis,** commonly called **sleeping sickness.**

This parasite is found in many invertebrates and vertebrates.

Its life history is divided into **two** stages. One a **flagellate monadine** ( ) phase, in which the organisms live in the blood-stream of vertebrates, in some of which they cause serious disease; the other is a **gregarine** ( ) **non-flagellate** phase which may also **be parasitic.** This latter type is met with in forms of Kala Azar.

This organism causes **sleeping sickness,** which is common in

West Africa. Those living on wooded shores of lakes and rivers, such as fishermen and canoe men, are subject to it. The parasite is carried by the bite of the **tsetse fly (glossina palpalis).** Wherever this insect is found the disease is likely to prevail. The fly lives on bushes on the shores of lakes or river banks, and feeds on the blood of crocodiles, antelopes, etc. The trypanosomes undergo various changes in the body of the fly. The infectivity does not appear until the thirty-second day, but continues for at least seventy-five days.

The parasite is found mostly in the **cerebro-spinal fluid** and less commonly in the blood. Hope of exterminating the disease seems to lie in exterminating the game (crocodiles especially) on which the tsetse fly feeds.

FLAGELLATES OF UNCERTAIN POSITION. (Fig. 58.)

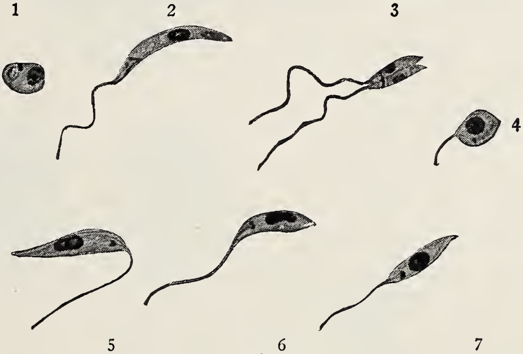


Fig. 58.

Kala-Azar organism. *1,* from a patient in India; *2* and *3,* individual flagellate, *(Leishmania Jonovani); 4, 5, 6* and *7, Leishmania infantum.* (From Kolle-Wassermann.)

Leishmania donovani.

Leishmania infantum.

Leishmania tropica.

Causes Indian Kala Azar (dum-dum fever), **Infantile Kala Azar,** and **tropical boil,** respectively. Common in Asia. Causes lesions on exposed surfaces of body, enlargement of the spleen, and anaemia.

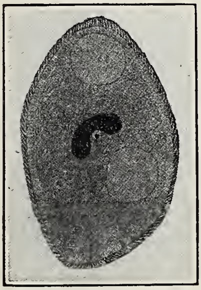


Fig. 59.

Balantidium coli, from an ulcer of man's intestine. (After Braun and Lühe.)

The bed-bug or a blood-sucking bug is probably the common carrier because ingested parasites undergoing development into flagellate forms have been found in the bed-bug.

The infantile disease affects **children only; probably through dog fleas,** as dogs are **spontaneously infected in the epidermic regions.**

Class IV. Infusoria.

Balantidium coli (or Entamoeba coli). (Fig. 59.)

A ciliated, oval-shaped infusorian with a bean-shaped marco-nucleus and a spherical micro-nucleus. The organisms frequently exhibit changes in form due to ameboid motion, as for example, when they penetrate the epithelial lining of the intestinal glands.

This parasite is a common inhabitant of the intestine of the hog but it causes no lesion there. On rare occasions it is apparently transferred to man where it gives rise to more or less extensive ulcerations in the large intestine (rarely in the lower end of the small intestine) accompanied by persistent diarrhea. The disease may terminate fatally.

These parasites are also found in the lumen and walls of the intestine, but usually they penetrate the epithelial wall and lie next to a gland. Some collect in the lymph-nodules. Often they are found in lymph-vessels and veins, but they do not seem to be distributed by the streams of these vessels. They have likewise been found in the liver.

They do not seem to produce a toxin but **do a mechanical injury only,** although this injury **opens paths through which bacteria often cause infections.**

The ulcers caused by this organism resemble those caused by **entamoeba histolytica.**

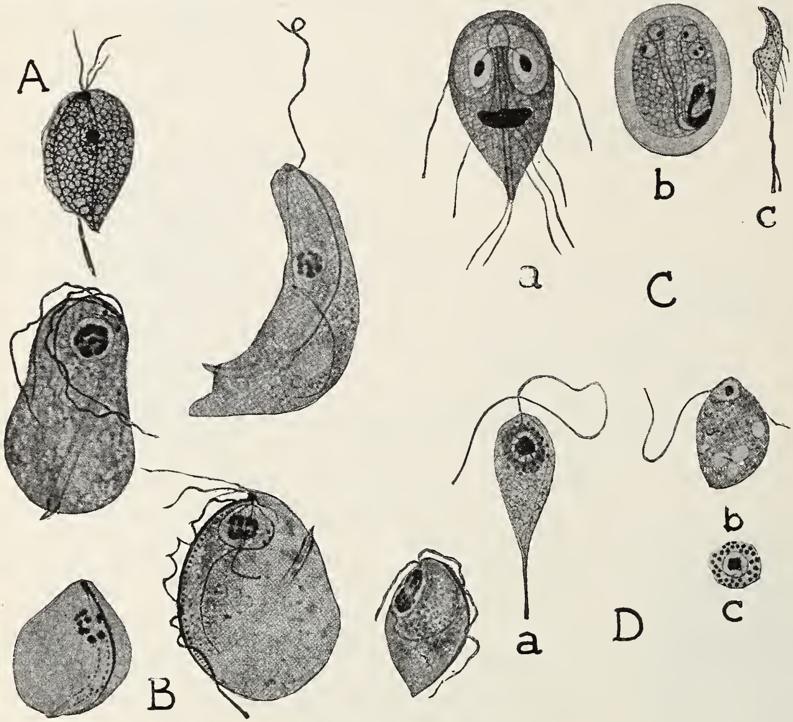


Fig. 60.

A. Partially schematic drawing of *Trichomonas intestinalis.*
B. *Trichomonas muris* dividing (5 stages).
C. *Lamblia intestinalis. a,* flagellated form; *b,* cyst; *c,* flagellated form viewed from the side.
D. *Cercomonas hominis. a* and *b,* show different forms of the organism; *c,* cyst.
(From Kolle-Wassermann; B, after von Kuczynski; C, after Benson and Grassi and Schewiakoff; D, after Wenyon.)

Trichomonas hominis (Fig. 60).

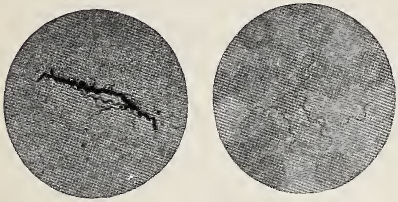
Cercomonas hominis.

In intestines, causing acute or chronic diarrhea.

Lamblia intestinalis.

Larger than the trichomonas. Flagellated forms have been found in the sputum of cases of gangrene of lung, and in those having pleurisy.

Borrelia recurrentis (formerly **Spirochaeta recurrentis**). (Fig. 61.)



1. 2.
Fig. 61.

1. *Borrelia recurrentis,* found in Russia.
2. Same as 1, but from a patient in Africa.
(From Kolle-Wassermann.)

Causes **Relapsing Fever** (also called **Famine Fever, Seven Day Fever, and Tick Fever**), probably transmitted by mosquitoes or bugs. From five to seven relapses take place after all symptoms have disappeared.

The spirillum or spirochete is 15 to 40 micra long, shaped like a corkscrew. Quite motile and present in blood during the febrile paroxysms, disappearing at intervals.

The disease has been reproduced by injecting into a healthy monkey the blood sucked by a bug from an infected animal.

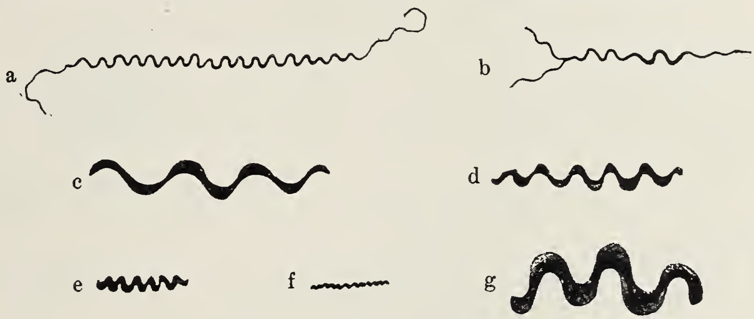


Fig. 62.

Schematic drawing of undulating membrane of Spirochaetes. *a* and *b Spirochaeta pallida; c, S. refringens; d,* a small Spirochaete of the same species; *e,* Spirochaete found in an ulcerated carcinoma; *f, Spirochaete dentium; g, Spirochaeta plicatilis* merely showing the extremity of a rather long individual. (After Schaudinn.)

Treponema Pallidum (Fig. 62).

Cause of **syphilis.**

Acquired syphilis is due to a mucous membrane coming in contact with the spirochete.

Congenital syphilis is transmitted through the mother to the child.

The **treponema** is a spiral, curved organism from five to fifteen microns in length, showing active movements in fresh specimens.

Syphilis is one of the most serious and far-reaching of all diseases, in fact so far-reaching that one of the world's greatest diagnosticians has said that, if one could know every ramification of this disease, he would know nearly all there was to medicine. It is doubtful whether the disease is curable.

Though all symptoms are gone, the disease may appear again.

In fact, in prisons, where there was little likelihood of a second infection, symptoms have appeared ten years after a supposed cure.

THE PROTOZOA, SUMMARY OF IMPORTANT FACTS

(Table Modified from R. Hertwig and R. W. Hegner.)

1. The **Protozoa** are **unicellular organisms without true organs or true tissues.**

2. All **vital processes** are accomplished **by** the **protoplasm** (sarcode), **digestion directly** by its substance, **locomotion** and the **taking of food by** means of **protoplasmic processes** (pseudopodia), **or** by **appendages** (cilia and flagella).

3. **Excretion** takes place **by** special accumulation of fluid, the **contractile vacuoles.**

4. **Reproduction** is **by budding** or by **fission. Conjugation** has been witnessed in many, and possibly occurs in all. True conjugation is a process of **fertilization** (caryogamy), in contrast to **fusion of plasma** (plasmogamy).

5. Protozoa are **aquatic,** a few living in moist earth. They can only exist in dry air in the **encysted** condition, surrounded by a **capsule which prevents desiccation.**

6. Since **encysted Protozoa** are easily carried by the wind, the occurrence of these animals in water which originally contained none is easily explained.

7. The mode of locomotion serves largely as a basis for division of the Protozoa into the classes **Rhizopoda, Mastigophora, Infusoria,** and **Sporozoa.**

8. The **Rhizopoda** are subdivided into the following orders: **Lobosa, Heliozoa, Radiolaria,** and **Foraminifera.**

9. The **Rhizopoda** have changeable protoplasmic processes, the pseudopodia.

10. Order 1. **Lobosa** ( ). Rhizopoda with fingerlike (lobose) pseudopodia. Most of the Lobosa occur in fresh water, a few in moist earth, and some are parasites.

Examples: **Amoeba, Arcella** and **Difflugia.** (Fig. 63 .)

Arcella ( ) is common in the ooze on the bottoms of fresh-water ponds and ditches. It has a dome-shaped brownish shell of chitin which it secretes. The lobose pseudopodia protrude from a circular opening in the center of the flattened surface.

Difflugia ( ) is another common member of the order Lobosa, and is also found in the ooze of ponds. Its shell consists of minute particles of sand and other foreign objects held together by chitin.

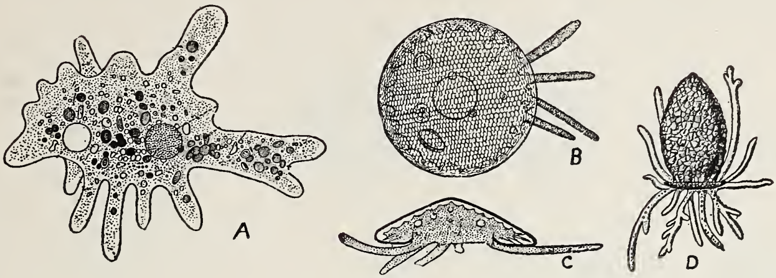


Fig. 63.

A. *Amoeba proteus.* (After Gruber.)
B. and C. *Arcella discoides.* (After Leidy.)
D. *Difflugia urceolata.* (After Leidy.)

11. Order 2. **Heliozoa** ( ) Rhizopoda with thin, radially arranged pseudopodia, which are usually supported by axial threads.

Examples: **Actinophrys.** (Fig. 64.)

Actinophrys ( ), the sun animalcule, lives among the aquatic plants in fresh-water ponds and ditches. The body appears vesicular, because it is crowded with vacuoles. The small organisms which serve as food strike the pseudopodia, pass down to the body, and are engulfed; larger organisms are drawn in by several neighboring pseudopodia acting together.

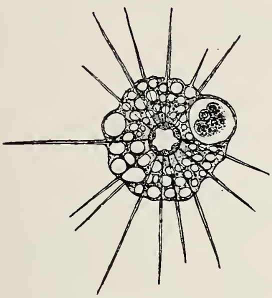


Fig. 64.
Actinophrys sol
(From Bronn.)

12. Order 3. **Radiolaria** ( ) Marine Rhizopoda with raylike pseudopodia, a central perforated capsule of chitin, and usually a larger enclosing skeleton of silica.

Examples: **Actinomma, Thalassicola.** (Fig. 65.)

The shells of the radiolarians, upon sinking to the sea bottom, form radiolarian ooze. This becomes hardened, producing rock strata as much as 1,000 feet thick. These rocks may take the form of quartzites, flint, or chert concretions.

13. Order 4. **Foraminifera** ( ) Rhizopoda, mostly marine, with fine, branching pseudopodia which fuse, forming a protoplasmic network.

Examples: **Allogromia, Globigerina.** (Fig. 66.)

Allogromia ( ) lives in fresh water and has a chitinous shell. The shells of many **Foraminifera** consist of numerous chambers connected by openings (foramina), and are composed of calcium carbonate. When these shells sink to the sea bottom, they become Globigerina ooze, which solidifies, forming gray chalk.

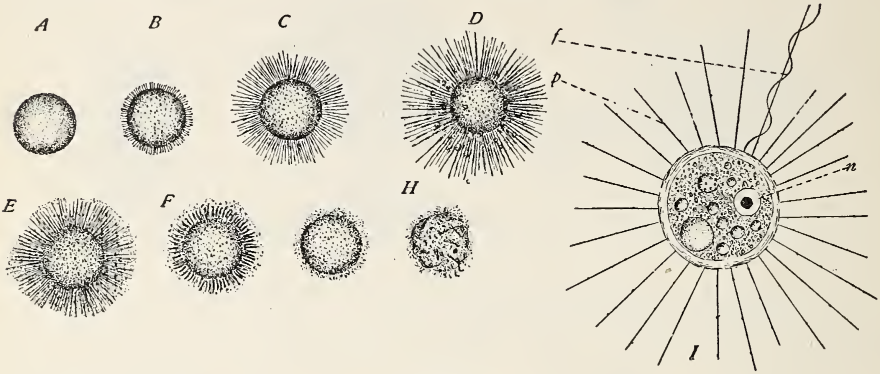


Fig. 65.
A. to H. Isolated Nucleus of *Thalassicola nucleata Hux.* (After Verworn.)
A. to D. Regenerative changes.
E. to H. Degenerative changes.
I. *Actinomonas Pusilla* (Kent) *n,* nucleus; *f,* flagellum; *p,* pseudopodia.

14. The **Mastigophora** ( ) may easily be distinguished from other Protozoa by the presence of one or more flagella. Four orders are usually recognized: (1) **Flagellata,** (2) **Choanaflagellata,** (3) **Dinoflagellata,** (4) **Cystoflagellata.**

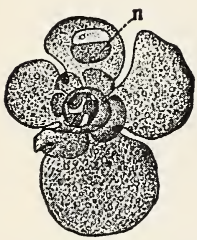


Fig. 66.
Protoplasm of *Globigerina,* after the shell has been dissolved. *n,* nucleus. (After Hertwig.)

15. Order 1. **Flagellata** ( ) Mastigophora with one or more flagella at the anterior end of the body.

Examples: **Euglena, Mastigamoeba, Chilomonas, Uroglena, Volvox.** (Fig. 67.)

Mastigamoeba ( ) is of special interest, since it appears to combine the distinguishing characteristics of both the Rhizopoda and Mastigophora; that is, it possesses pseudopodia

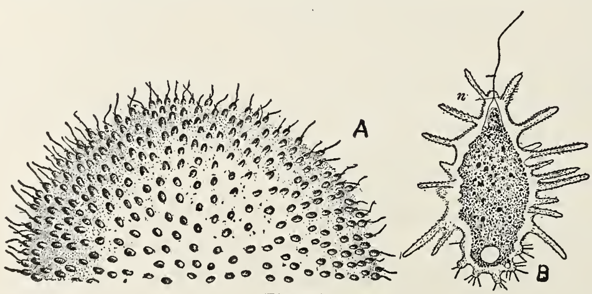


Fig. 67.
A. *Uroglena americana,* Calkins, a sphareoid colony.
B. *Mastigamoeba aspera.* (After Schultze.)

and also a distinct flagellum. It is, therefore, able to creep about on a solid object, or swim directly through the water.

Chilomonas ( ) is a very common flagellate in laboratory cultures. **Uroglena** forms spheroidal colonies consisting of a great number of individuals held together by a gelatinous matrix. This form is often responsible for the **"oily odor"** of drinking water, caused by the escape of small droplets of an oily substance from the cells.

Volvox ( ) (Fig. 49) is a colonial flagellate found in fresh-water ponds. It may consist of as many as twelve thousand cells. Protoplasmic strands connect each cell with those that surround it; **physiological continuity** is thus established. All of the cells are not alike, since some of them, the **germ cells**, are able to produce new

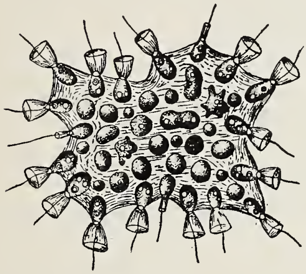
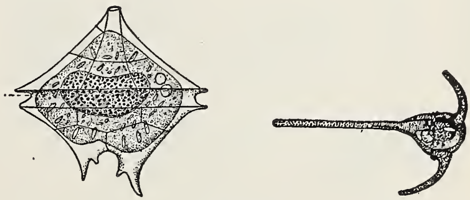


Fig. 68.

Proterospongia haeckeli S. K. (S. Kent.)



A. B.

Fig. 69.

A. *Peredinium divergens, chr.*
B. *Ceratium tripos* (Calkins). (From Pratt's "Manual" by permission of A. C. McClurg & Co.)

colonies, while others, called **somatic** or **body cells**, have no reproductive power.

Some of the germ cells, the **parthenogondia** ( ), grow large, divide into many cells, drop into the center of the mother colony, and finally escape through a break in the wall. Other germ

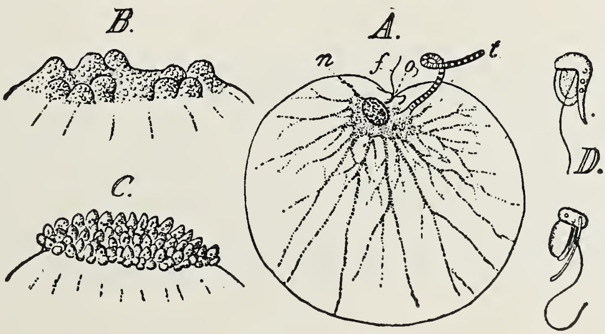


Fig. 70.

Noctiluca millaris. A, entire animal; *f*, flagellum; *n*, nucleus; *o*, cytostome and beside it the tooth and lip; *t*, tentacle; B, C, upper end with two stages in the formation of zoospores; D, zoospores. (After Hertwig.)

cells produce by division a great number of minute microgametes or **spermatozoa**, and still others grow large, becoming macrogametes or **eggs**. The eggs are fertilized by the spermatozoa, and, after a resting stage, develop into new colonies.

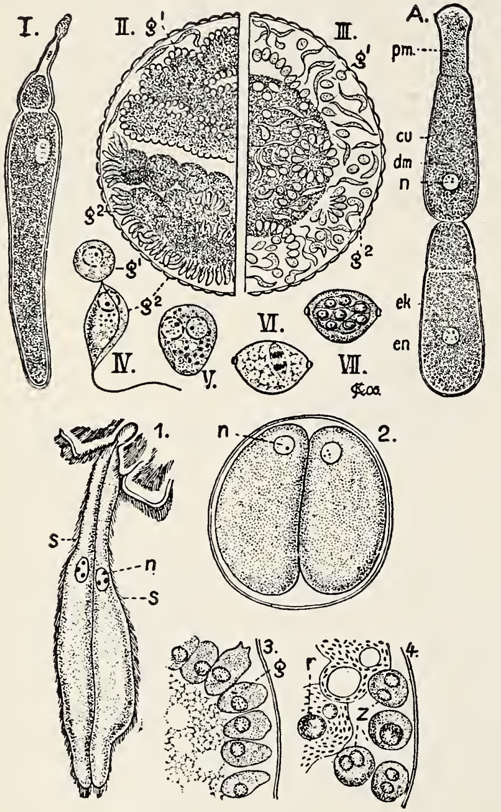


Fig. 71.

Different Gregarina. *I-VII*, development of *Stylorhynchus; I*, S. *longicollis; II*, encysted S. *oblongatus* (two animals) beginning gamete formation; *III*, same later when the sexually differentiated gametes are copulating; *IV-VII*, formation and development of zygote of S. *longicollis* more enlarged; *IV*, copulation of gametes; *V*, A, *Clepsidrina blattarum*. *1-4*, *Monocystis magna*. *1*, two individuals copulating while in the spermatheca of an earthworm, surrounded by spermatozoa; *2*, encysted; *3* and *4*, parts of cysts, formation and conjugation of the more enlarged gametes. *cu*, cuticula; *dm*, deutomerite; *ek*, ectosarc; *en*, entosarc; *g*, gametes; *g1*, zoospores; *g2*, oospore; *pm*, protomerite; *n*, nucleus; *r*, residual body; *s*, sperm of earthworm; *z*, zygote. (From Hertwig after various authors.)

16. Order 2. **Choanoflagellata** ( ) Mastigophora with a contractile protoplasmic collar from the bottom of which extends a single flagellum.

Examples: **Monosiga, Proterospongia.** (Fig. 68.)

17. Order 3. **Dinoflagellata** ( ) Mastigophora with two flagella, one at the anterior end, the other passing around the body, often in a groove.

Examples: **Peridinium, Ceratium.** (Fig. 69.)

18. Order 4. **Cystoflagellata** ( ) Mastigophora with two flagella, one resembling a tentacle, the other lying in the gullet.

Examples: **Noctiluca, Leptodiscus.** (Fig. 70.)

Enormous numbers of **Noctiluca** ( ) are often found floating near the surface of the sea, giving it the appearance, as Haeckel says, of "tomato soup." At night they are phosphorescent, emitting a bluish or greenish light.

19. The **Sporozoa** ( ) are Protozoa without motile organs. They are **parasitic in Metazoa.** Reproduction is mainly by spore formation. The following classification is simplified from Minchin's account in Lankester's **Treatise on Zoölogy**, Part 1:

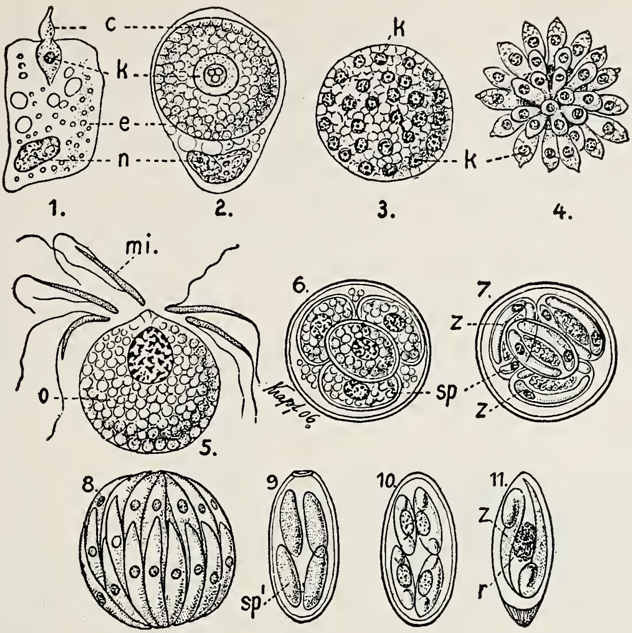


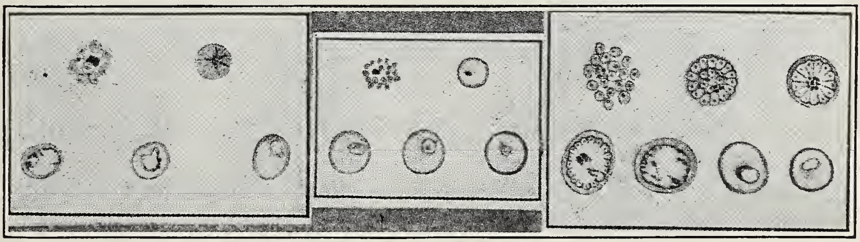
Fig. 72.

Development of *Coccidium schubergi* *1*, entrance of sporozoites in cell; *2*, its growth; *3*, nuclear multiplication; *4*, division into merozoites; *5*, macro-and microgametes; *6*, zygote divided into four sporozoites. *8-11*, *Emeria stiedae*. *8*, auto-infection; *9*, formation of sporoblasts; *10*, change of spores into sporozoites; *11*, spore with two sporozoites, much enlarged; *c*, *z*, sporozoite; *e*, epithelial cell; *k*, *n*, nucleus; *mi*, microgamete; *o*, macrogamete; *r*, residual body; *sp*, spore; *sp'*, sporoblasts. (1-7 after Schaudinn; 8-11 after Wasielewsky and Metzner.)

20. Subclass 1. **Telosporidia** ( ) Sporozoa in which the life of the individual ends in spore formation.

21. Order 1. **Gregarinida** ( ) Telosporidia possessing a firm pellicle and complex ectosarc; intracellular during the early stages of the life cycle, later free in the body cavities of invertebrates.

Examples: **Monocystis, Porospora, Gregarina.** (Fig. 71.)



A. B. C.

Fig. 73. *Plasmodium malariae.*

A. Parasites of tertian malaria.
B. Parasites of estivo-autumnal malaria.
C. Parasites of quartan malaria. (After Thayer and Hewetson.)
(From supplement No. 18 to the Public Health Service, Jan. 20, 1915.)

Monocysts ( ) may be found in the seminal vesicles of almost every earth-worm; **Gregarina** is a common parasite of the cockroach; and **Porospora gigantea,** which reaches a length of two-thirds of an inch, inhabits the alimentary canal of the lobster.

22. Order 2. **Coccidiidea** ( ) Telosporidia simple in structure; trophozoite is a minute intracellular parasite.

Example: **Coccidium.** (Fig. 72.)

Members of this order are sometimes found in the liver and intestine of man and other vertebrates, and in Arthropoda and Mollusca.

23. Order 3. **Haemosporidia** ( ) Telosporidia parasitic in the blood of vertebrates.

Example: **Plasmodium.** (Fig. 73.)

24. Subclass 2. **Neosporidia** ( ) Sporozoa which give rise to spores at intervals during active life.

Fig. 74.

Nosema. Longitudinal section of stomach of honeybee showing infection with *Nosema apis: ep,* Epithelial portion, containing spores of the parasite stained black. (The younger parasites, not differentiated so easily by staining, are not shown; they are found toward the base of the cells reaching the basement membrane *(bm),* but do not extend beyond it. Younger spores sometimes show an unstained area at one end and occasionally at both ends. *m,* muscular portion of stomach wall showing an outer and an inner longitudinal muscular layer and a middle circular one. (After G. F. White, U. S. Dept. of Agriculture Bulletin No. 780.)

25. Order 1. **Myxosporidia** ( ) Neosporidia with ameboid intercellular trophozoite.

Example: **Nosema.** (Fig. 74.)

The Myxosporidia are parasitic especially in Arthropoda and fish, frequently causing serious epidemics in aquaria. **Nosema bombycis** produces the silkworm disease, **pebrine.**

26. Order 2. **Sarcosporidia** ( ) Neosporidia usually parasitic in the muscles of vertebrates.

Example: **Sarcocystis.** (Fig. 75.)

The most common Sarcosporidia are **Sarcocystis miescheriana** in the muscle of the pig; **S. muris,** in that of the mouse; **S. lindemanni,** rarely occurring in the muscles of human beings.

27. **The Infusoria** ( ) are protozoa with cilia which serve as locomotor organs and for procuring food. **Paramoecium** is a typical member of the class. There are two subclasses, (1) **Ciliata,** and (2) **Suctoria.**

28. Subclass 1. **Ciliata** ( ) Infusoria with cilia in the adult stage, a mouth, and usually undulating membranes or cirri. Many ciliates are confined to fresh water, others occur either in fresh or salt water, and still others are parasitic in Metozoa.

29. There are four orders: (1) **Holotricha,** (2) **Heterotricha,** (3) **Hypotricha,** (4) **Petritricha.**

30. Order 1. **Holotricha** ( ) Ciliata with cilia all over the body and of approximately equal length and thickness.

Examples: **Paramoecium, Coleps, Loxophyllum, Colpoda, Opalina.** (Fig. 76.)

The Holotricha are probably the most primitive Infusoria. **Paramoecium caudatum** is the best known species. Members of the following genera are frequently found in fresh-water cultures: **Coleps, Loxophyllum,** and **Colpoda. Opalina ranarum** is a large multi-nucleate species living in the intestine of the frog. It has no mouth, but absorbs digested foods through the surface.

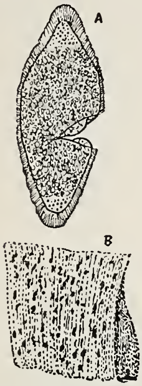
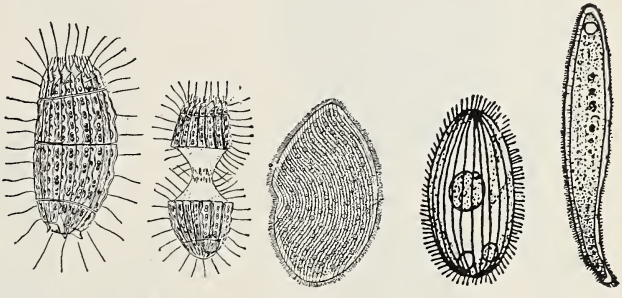


Fig. 75. *Sarcocystis miescheriana.* (Doflein.)
A, a cyst; B, Pork containing cysts. (From Pratt's "Manual" by permission of A. C. McClurg & Co.)



A. B. C. D. E.

Fig. 76.

A. *Coleps hirtus Ehr.* (After Maupas.)
B. Division phase of A.
C. *Opalina ranarum.* (After Bronn.)
D. *Colpidium colpoda.* (Calkins.)
E. *Loxophyllum rostratum.* (Conn.)

31. Order 2. **Heterotricha** ( ) Ciliata whose cilia cover the entire body, but are **larger and stronger about the mouth** opening than elsewhere. This adoral ciliated spiral consists of rows of cilia fused into membranelles and leads into the mouth.

Examples: **Spirostomum, Bursaria,** and **Stentor.** (Fig. 77.)

Stentor ( ) may be either fixed or free swimming. It is trumpet-shaped when attached and pear-shaped when swimming. The cuticle is striated and just beneath it are muscle fibers (myonemes). The nucleus is ellipsoidal, or like a row of beads.

32. Order 3. **Hypotricha** ( ) Ciliata with a **flattened body** and dorsal and ventral surfaces. The **dorsal surface is free from cilia,** but **spines may be present.** The ventral surface is provided with longitudinal rows of cilia and also spines and hooked cirri, which are used as locomotor organs in creeping about. The cilia around the oral groove aid in swimming as well as in food taking. There are a macronucleus, often divided, and two or four micronuclei.

Examples: **Oxytricha, Stylonychia.** (Fig. 78.)

33. Order 4. **Peritricha** ( ) Ciliata with an

adoral ciliated spiral, the rest of the body is without cilia, except in a few species where a circlet of cilia occurs near the aboral end.

Examples: **Vorticella, Carchesium, Zoothamnium.** (Fig. 79.)

The common members of this order are bell-shaped and attached by a contractile stalk. Certain species are solitary (**Vorticella**), others form tree-like colonies (**Carchesium**), and still others are colonial but

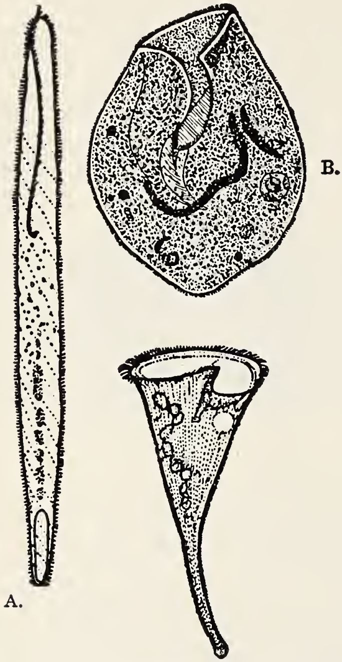


Fig. 77.

A. *Spirostomum teres* (Conn).
B. *Bursaria truncatella* (Conn).
C. *Condylostoma patens.* (Calkins.)
(From Pratt's "Manual" by permission of A. C. McClurg & Co.)

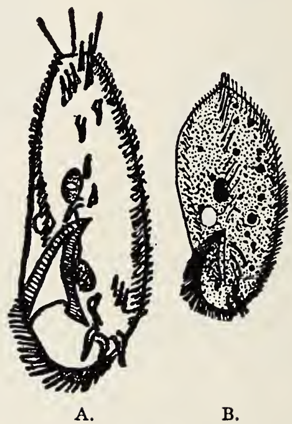


Fig. 78.
A. *Oxytricha bifaria* (Conn).
B. *Stylonychia mytilus* (Doflein).
(From Pratt's "Manual" by permission of A. C. McClurg & Co.)

with an enveloping mass of jelly (**Zoothamnium**). The stalk contains a winding fiber composed of myoneme fibrils; this fiber, on contracting, draws the stalk into a shape like a coil spring.

34. Subclass 2. **Suctoria** ( ) Infusoria **without cilia in the adult stage.** No locomotor organs are present, and the animals are attached either directly or by a stalk. An oral groove or mouth does not occur, but a number of tube-like tentacles extend out through the cuticle.

Examples: **Podophyra, Sphaerophyra.** (Fig. 80.)

Ciliates are captured by the tentacles and the substance of the

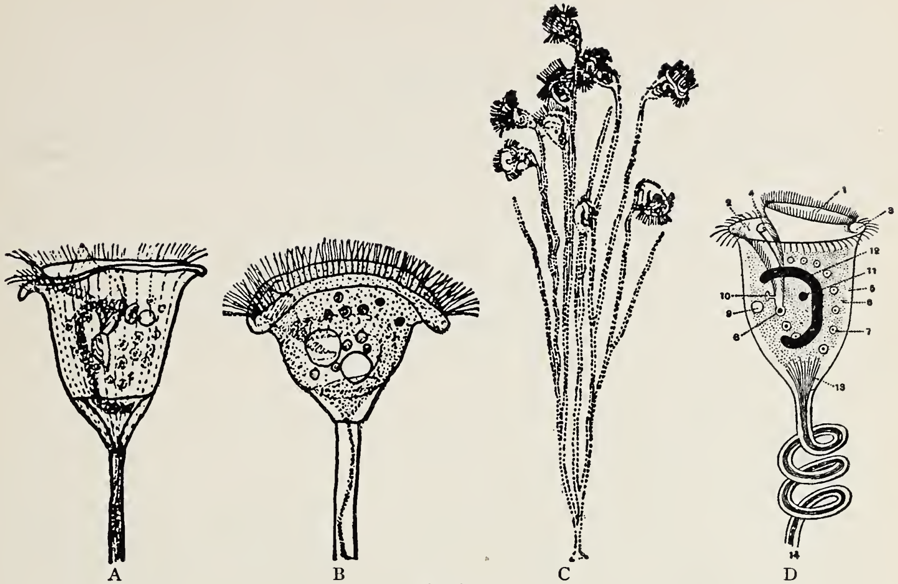


Fig. 79.

A. *Vorticella nebulifera* (Bronn).
B. *Vorticella patellina* (Calkins).
C. *Carchesium polypinum* (Doflein).
D. Diagram of *Vorticella*. The cilia at the side of the mouth have been omitted. (From Pratt's "Manual" by permission of A. C. McClurg & Co.)

captured prey is sucked into the body. Both fresh-water and marine species are known. **Podophyra** is a well-known fresh-water form. **Sphaerophyra** is parasitic in other Infusoria.

Fig. 80.

Podophyra gracilis. (Calkins.) (From Pratt's "Manual" by permission of A. C. McClurg & Co.)

CHAPTER X

INTERPRETATIONS OF THE FACTS THUS FAR PRESENTED

THE far-reaching importance of Biology may be shown by obtaining an understanding of this fact: When anyone wishes to discuss **inheritance, environment, training,** or any of the many philosophies, or **theories of life,** some **physical** (biological) **background** must be found, or the discussion is not likely to impress many persons. A conception of such background may be gained by reviewing the following facts just studied:

The little cigar-shaped animal known as **Paramoecium** is found in fresh water. It moves about rapidly by means of tiny hair-like projections which cover its entire body. Although there are in reality **only two reactions** to any obstacle encountered, it **goes forward** and **backward** turning its body over and over so that its path is spiral-shaped. A groove extends half way down the length of the body into which particles of food are swept as the animal moves forward. Since the mouth is located at the lower end of this groove, the food is thus conveniently forced into it and swallowed.

The entire animal is composed of a thick substance which appears something like the white of an egg. That this thickened material is not homogeneous is attested by the fact that a drop of alcohol placed upon it causes the outer portion of the animal's body to swell up like a blister, while the same alcohol apparently has no effect upon the more internal structure. Then, too, if **Paramoecia** are placed in a staining fluid, **two regions** take the color much better and much deeper than do other parts of the body, showing that the two regions, which thus take the stain, are of different chemical composition from the other parts. Were all the substance alike, it would all stain alike. These stainable regions are the **nuclei.**

Everyone has observed that all living things which fulfill their normal span of life are subject to the same natural laws, such as being born, growing to maturity, and dying. The nearest thing to an exception to this general rule is found in the little single-celled animal of which we are speaking. This animal is **not born.** When it is time for the **Paramoecium's** parent to pass from this earthly region as an individual, the animal merely divides into two separate and distinct organisms. (Fig. 81.)

There are now two **Paramoecia** where there was only one before. This is significant. The two new animals **(each consisting of one-half of its parent)** again divide into two separate animals, and so continue dividing indefinitely. The greatest number of divisions observed so far is six thousand. This means that **Paramoecia** do not die, though they can be killed, e.g., by boiling, by immersion in acids, and in other ways. It means further, that every **Paramoecium** in existence is **actually a part of all its ancestors**; or more accurately, **it is its ancestors**, for these ancestors have never ceased to be. This must be true, because each ancestor merely divided into two offspring, the offspring being in reality the parent itself. This is different from a parent giving birth to an offspring and then dying.

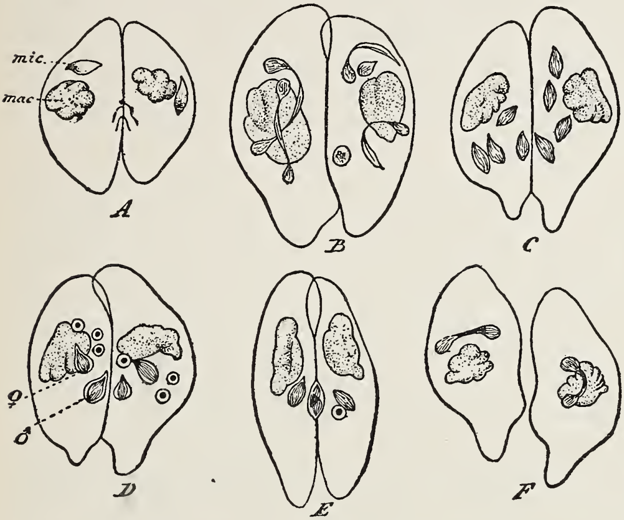


Fig. 81.
Stages in the conjugation of *Paramoecium caudatum*. *A*, Stage A, the micronucleus in each gamete preparing for division. *B*, Stage B, the daughter nuclei in each gamete dividing. *C*, Four micronuclei in each gamete. *D*, three of the four micronuclei are disintegrating; the surviving nucleus in each gamete has divided to form ♂, the male, and ♀, the female pronucleus. *F*, The male pronuclei crossing over. *F*, Conjugation effected; separation of the gametes and division of the combination nucleus. (After Maupas.)

It is an established biological fact that **no living cell can come from anything but a previous living cell. No organism or living thing can come into existence except from some previously existing living parent form.**

Now, if sufficient food is given **Paramoecia**, they keep on dividing several hundred times; but, if they are with others of their kind, an interesting event takes place. Two of the animals will swim around, finally attaching themselves to each other lengthwise, while the wall of each animal which is in contact with its mate seems to disappear, the two animals becoming **almost**, but not quite, one.

The smaller colorable spot in each animal now begins to divide into two parts as shown in Fig. 81. These parts again divide, making four pieces of each nucleus. Three of these pieces disappear (probably are dissolved in the body substance). The one remaining piece then divides into two pieces, one of which remains more or less stationary, while the other (often partially connected with the first) moves toward the midline of the two connected animals to meet with a similar movable piece of stainable matter from the attached individual. The two pieces of movable, stainable matter **become one for a short period**, seemingly exchanging some of their substance. Then they again separate and form a nucleus like the one from which they sprang.

The animals themselves now separate, and each divides into two new animals. These again divide, such division continuing as already mentioned, several hundred times, until this same **conjugation** or joining process occurs again. The larger stainable spot is dissolved at the time of conjugation and is thought to have some nutrient function.

It is the **nuclear material** which seems to be the **important physical matter** in the formation of any living thing—plant or animal—and, in turn, it is only the colorable matter inside the nucleus known as **chromatin,** which breaks up and divides (the separate parts are now called **chromosomes),** and is carried on from parent to offspring. The chromosomes are now considered the most important factors which throw light on the many problems of inheritance—that is, on all problems pertaining to characteristics actually obtained from our parents, whether these are physical, emotional, or intellectual.

It is, therefore, of decided importance that we obtain a clear conception of chromosomes, because in the final analysis every detail of what we are and can be, that has any relation whatever to our physical, emotional, and mental makeup, must come from our parents through the chromosomes in the egg cell of the mother and the sperm cell of the father. In other words, the chromosomes that were ours at the moment of mixture of sperm and egg, possessed the sum total of all the factors producing the physical, mental, and emotional endowment with which we were possessed when ushered into the world (except the food and environment needed for growth, and a place to grow).

In **Paramoecia, the animal does not inherit anything from its parent —it is half of its parent.** Each **Paramoecium** is thus equivalent to an egg cell or a sperm cell. **The offspring is not a chip from the old block— it is half the block.**

An interesting application follows:

In every living thing, where observation of chromosome material has been possible, life begins from a single cell of some kind. In the higher forms, this (egg cell) receives one half the chromosomes from the sperm after the egg cell has cast out one half of its own chromosomes. There is thus a constant trend toward forming an individual who approaches the **average** individual of the species to which each such individual belongs, for, each new living thing is made up of one half the chromosomes which the maternal egg cell possessed, and one half of those which the paternal sperm cell contained.

If this were not so, then those cases in the animal world which have virgin birth, would have an ever lessening quantity of the chromosome material in each next generation. Each offspring would then become more unlike its parent, until in time, when no fertilization takes place to restore the proper quantity of chromosome material by a paternal sperm cell being added to the maternal egg cell, the offspring would not be recognized as a member of the species to which its ancestors belonged.

In every female, in the higher forms, at the time of birth **the substance of the germ tract is already segregated so that practically every egg in her body that she will ever have is present.** This is as true of a bird as of a human being. The human has about 35,000 eggs in each of the two ovaries, though only about 100 to 200 of these actually ripen and pass out of the body during the sexual life of the individual. This means that the mother has little or no influence **on the formation** of the egg, **because it is already complete by the time she is born.**

The eggs lie dormant and do not begin to ripen until sexual life begins (averaging from twelve to fifteen years in the human being). But, when an egg ripens, an interesting process takes place. The egg is expelled from the ovary immediately and, just as **Paramoecia** split into two parts, so does the egg. But the **egg does not divide equally.** A little piece, called the **polar body,** separates from the main part of the egg. This polar body may divide again, but even so, it deteriorates and cannot be seen in a short time. The stainable nuclear material breaks up into a number of chromosomes just like the chromatin of the **Paramoecium.** One half of these chromosomes remain in the larger portion, the other half passes into the polar body to deteriorate with that part.

The **head** of the male cell (spermatozoan) **is practically all nuclear material** and goes through approximately the same process as the egg, except that the sperm divides **equally as to size,** thus forming **two definite, living sperm cells where there was only one before**—again, this is quite like **Paramoecia.** And here, too, the chromosomes divide equally, so that each sperm has only one half the full number of chromosomes it had before it divided.

As practically all plants and animals come into existence in practically the same way, through uniting a single cell of the male and a single cell of the female, we see that this is nature's way of bringing together the **normal number of chromosomes needed to make a complete individual.** Thus, each individual comes into possession of one half the traits or capacities of each **parent cell** (not necessarily one half of the traits or capacities of the parent) from which he sprang. Were this not true, all of us would be quite unlike our parents, because we would be less than either parent, instead of taking one half from each parent, thus becoming a complete human being. As our parents can give us but the single egg cell and the single sperm cell, everything else being merely food and environment, everything we can possibly inherit must be present in the fertilized egg. The precision with which the cell divides its chromatin equally between the two daughter cells in mitosis indicates the importance of the chromosomes. In fact, it has been shown that these bodies are the all important part of the cell from the point of view of heredity, as they are the carriers of the genes. The cytoplasm seems to play but a small part in the rôle of heredity.

For anyone wishing to study life, therefore, the study of **chromosomes** looms up as **the most important factor.**

The laboratory study of the fertilized cell, of which we speak, has shown that each such fertilized cell divides into two cells; these two into four; each of these four into two, making eight; these eight into sixteen; and so on indefinitely until the entire body has finished its growth.

The first group or sheet of cells becomes a **hollow sphere** called a **blastula.** The blastula continues growing, which means that this single-layered sphere **indents,** and this indentation extends into the sphere until **two layers** of cells are formed. This is called the **gastrula** stage. Animals having two layers stop growth when this stage is reached, while all higher forms produce a **third layer** of cells between these two.

Every living animal passes through one or more of these developmental processes. This fact led so many of the early biologists to suppose that each developmental stage meant that each one of the higher forms of animals must have sprung from those which stopped in the one- and two-layer stage just beneath the higher form. It means, however, that all living forms pass through a **similar** state of growth.[1]

Very early in this development of an egg, **after** it begins to grow (fertilization apparently furnishes this growth impulse), **certain cells divide much more rapidly** than do others. The rapid-growing cells, consequently, soon **surround the less-rapidly** growing ones, thus forming a sort of protecting case or capsule for them. Now, some of the very first cells that are thus protected and grow into the very innermost portions of the growing **embryo,** are the egg-cells and the sperm-mother cells. This occurs long before one can even distinguish what kind of an animal the embryo is to become.

It was Professor August Weismann of the University of Freiburg in Baden, who in 1892 gave the world his book, "The Germ-plasm, a Theory of Heredity," which has made us interpret the various facts so far mentioned in a different way from what had been done before. Up to that time men said that the reason a boy so closely resembled his father was because he was "a chip **from** the old block." Professor Weismann has shown us that this is incorrect, and **that both father and son are pieces from the same block.** That is, the **sex-cells in both mother** and **father,** being a part of the earliest differentiation in the growing embryo as already shown, are really placed in position in the child **before he is born,** so that a parent, simply considered as a parent, has absolutely nothing whatever to do with the matter, such parent's body acting only as a case or capsule which carries the germ-cell to the next generation.

This is made clearer when it is remembered that every egg in the female is already present at the time of such individual's birth. All that happens during her life is a **ripening,** or **maturing,** of such egg, and fertilization by the male sperm. The sperm-mother-cells which are to divide and form sperm, are **already present** in the male child when he is born, though they begin to divide only after puberty.

The sex-cells are, therefore, present at birth in each person, and it

[1]It does not follow that because a man builds a school, a barn, and a church, that the church must therefore have first been a school and a barn, even though such builder used exactly the same tools and similar material in the building of each structure; in fact, it would not follow, even though he build the foundation and the first story of each structure exactly alike in each case.

has not yet been proved that one can either change or add anything to them, unless, again it be merely the food and drink he takes which may or may not nourish such sex-cell properly.

This means, then, that just as with **Paramoecia**, each and every one of us cannot obtain from our parents one more particle of physical, emotional, or mental ability than our parents may have had, because we get only what was present in the egg-cell of our mothers and the sperm-cell of our fathers.

It means further, that when we go back even twenty-five generations, considering our two parents, four grandparents, eight great-grandparents, etc., we are related in actual blood-relationship to more people than there are in the world at the present time. It means that just as **Paramoecia** are really their grandparents and all their ancestors in one, so **we are also actually and truly our own ancestors in so far as our sex-cells are concerned.**

An actual living particle of every one of our forefathers is really present in each one of us. It means that the entire animal world, including the human family, by constant intermingling of chromosomes, is always tending toward **an average**, so that **no matter how many centuries elapse, no real, individual, physical, or biological progress is possible. Always will the next succeeding generation, or at least the next after that, have some sex-cells in their bodies which will again produce an average being.**

This **sex-bridge** which connects every human being with every other human being in this way, is sometimes referred to as the **Weismannian bridge.** It is this bridge which is both the hope of an oppressed people and the despair of those who would change human nature from what it is. We can build only upon instincts and on human desires and wishes which are in turn the result of the instincts we were born with. We may **develop** such instincts and desires, **but no actual change in human nature can possibly ever come into existence.** Human nature is the same now as it has ever been and always must be, until some method be obtained by which we can tell in advance by looking at a chromosome, what good and bad characteristics such chromosome contains, and then be able to destroy the bad therein. This means that we are aeons and aeons removed from any solution to our **eugenic problem** on a **truly scientific basis.** Even then, were we able to accomplish this practically impossible task, we should still have to evolve some plan by which we could see the egg and the sperm before they unite, a task again practically impossible until **new** human beings can be grown in the laboratory.

Professor Weismann also demonstrated to the scientific world that the germ-plasm **early separates** from that part which is to become the **outer portion** of the body and which is called the **somatoplasm.**

The **Abbott Mendel** has proved that no matter how much interbreeding there may be among plants or animals, there are only two types of offspring produced, i. e., **pure stock** and **half-breeds.**[1] The eggs and **sperm** in the germ-plasm **always remain pure.** That is, if a **white** and **black** animal **mate, a portion of the eggs** in the ovary of any female offspring from such union will be **carriers** of **pure black,** and **a portion** will be **carriers** of **pure white characteristics.** The **sperm** of the male, **likewise,** are **carriers** of **one or the other colors,** but are **not themselves half-breed.** It will be noticed, therefore, that from this **Mendelian theory** additional evidence is brought forth to substantiate the Weismannian theory of germ-plasm, which holds that the germ-plasm is separate and distinct from the rest of the body.

The **color of the skin** of any offspring **of black and white** animals may be of **any shade,** from pure black, to almost, or entirely white. **But the sperm and the egg have not intermingled in so far as color is concerned.** The **color** shows up on the **outer part** of the body, or in what we call the **somatoplasm.** The **germ-plasm always remains pure**, so that in the next succeeding generation, if any of these half-breeds in turn mate with each other, we have the four possibilities of a sperm carrying the genes for whiteness meeting with an egg carrying the genes of blackness and again producing a half-breed, or a sperm carrying genes of blackness meeting with an egg carrying genes of blackness and producing a pure black, while a sperm carrying the genes of blackness mating with an egg carrying the genes of whiteness, produces a half-breed, and a sperm carrying genes of whiteness with an egg carrying genes of whiteness produces a pure white.

From observation, however, it is found that most **half-breeds will look like one or the other of their parents in so far as color** of skin, eyes, and hair is concerned. **Whatever color** the offspring shows, is known as the **dominant** color.[2] We cannot tell, however, until we observe the first brood of half-breeds which is the dominant color.

We do not know why one characteristic is thus dominant, but the important thing to remember is that this entire possibility of any of the four possible matings mentioned above taking place in any mixed offspring, is all a **matter of chance.** Having observed thousands of instances of this kind among both plants and animals, scientific men now accept it as a fact that we **do** obtain **two individuals of pure stock,** and **two half-breeds** from matings of mixed ancestry. It will be noticed

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[1]This refers to the crossing of two pure breeds, of course.

[2]*Recessive* is the word set in opposition to *dominant.* A recessive characteristic is *always present* in the germ-plasm of an animal or plant of *mixed ancestry,* but it *does not show* in the somatoplasm—in any part of the *body proper outside the germ-plasm.* The dominant characteristics *cover up the* recessive characteristics. For example, in half-breed offspring—a cross between white and black parents—if all these half-breeds are black, we call *black* the dominant characteristic *as to color,* though such half-breed has just as much *white* in him as he has black. The white which is *present but which is not seen* is called the recessive characteristic.

It is very important, however, to remember that in so far as the germ-plasm—the sex cells themselves, that is, the eggs and sperm—is concerned, each egg and each sperm has, roughly speaking, *one-half* black and *one-half* white characteristics; but the *dominant characteristic* is the only one which *shows,* and that only in that part of one's make-up *which is not germ-plasm.*

To clarify the matter; if half-breeds, which are the offspring of black and white parents are *all black,* we call *black* the dominant color.

that this is **pure chance**, there being approximately **half as many carriers** of **either color** in **each sperm of the male** as there is **in each egg of the female.** Therefore, there is just as much likelihood at any given time of a sperm carrying blackness meeting with an egg carrying whiteness as of one carrying whiteness meeting one carrying blackness and vice versa. But it must not be forgotten **that not only the half-breeds**, but **also the pure bloods of the dominant type** will **all** probably **look alike** as to color. This appearance of the **same color in the half-breeds**, which appeared in the dominant pure-blood, is the thing which confused men for many years, and it was only after Abbott Mendel gave us his explanation that we have been able to understand why this is so.

Mendelism has also added some interesting biological speculations to the earlier ideas of naturalists.

If we define **species** as meaning **all those particular plants and animals which can interbreed** and in turn give birth to fertile offspring, it can be seen immediately that we cannot have any **new species** at all. For, if the offspring of such plants or animals can give birth in turn to other offspring, they belong to the **same species** as do their parents, and, if they differ in appearance from their parents, they can only be called **variations** of the parent species. If they do not interbreed, or, if after interbreeding, they give birth to non-fertile offspring (such as the **mule**, which is the non-fertile offspring of a mare and a jack), then, of course, there can be no further offspring, and we can have no further species.

Mendelism has added a very important and interesting fact to such theorizing. For example, in the **dominant type of offspring of pure-bred parents**, there are always **pure sperm and eggs** which **carry recessive characteristics**, so that it follows, that **at any time in the future, if by chance such pure egg and sperm meet**, a **totally different** type of plant or animal may be produced. But this may be merely **the coming forth** of a plant or animal **similar to some ancestral form**, which was the result of two germ-cells meeting that carried the recessive trait. Therefore, although these recessive germ-cells were always present in all ancestors, they were **covered up** in so far as external characteristics are concerned by the dominant characteristics. A new species, such as this which comes forth **suddenly**, is called a "**sport**" in nature, and the theory that all new forms come forth in this way is called the **mutation theory**. But, as these so-called new forms may be explained as being **recessives, again coming forth** after lying dormant for ages, there may be here no new species at all.

CHAPTER XI

GENETICS

WITH a clear understanding of what has been said regarding the division of chromosomes in maturation, in a former chapter, and the discussion of interpretations in Chapter X, we are in a position to understand the terminology of heredity, genetics, and Mendelism, which is met with quite commonly in modern biological literature.

While genetics really means the "origin of things" it has come to be used as the name of that science which studies the ways and means by which **minor inheritable characters can be judged.** It must never be forgotten that to inherit anything from one's parents in the biological sense, means that the "something" which is inherited must already be present in the egg of the mother, or the sperm of the father, or in both these germ cells, at the time the egg is fertilized. Every factor that may influence an organism, which is not already present in the gametes, is due to environmental conditions and cannot be said to be inherited.

At this point we must also remember the distinction made in a former chapter that germplasm and somatoplasm are entirely separate and distinct.

Mendelism, or rather Mendel's "law," merely means that each characteristic that we may inherit must be considered as **a single unit.** To illustrate, we must not think of a child as inheriting its father's hair because it has dark curly hair like its father, but we must think of darkness in color as one character of inheritance and curliness as another; for, a child may inherit the darkness in color from its mother and the curliness from its father.

Thinking in terms of **unit characters** will throw much light upon many of the interesting problems of life. We may thus account for one artist, for example, having a very decided sense of **form** and another of **color.**

It is now generally conceded by biologists that acquired characteristics are not transmitted to the offspring. We know, however, that brothers and sisters of the same family differ from each other in many respects. We know that no two leaves of grass are exactly alike; in other words, that all living things springing from the same parents vary somewhat from each other. It is the purpose of genetics **to find the mechanism by which such variation takes place,** and then to be able to apply the knowledge thus gained toward bringing about the types of variations one wishes. Every variation represents a single unit character or a combination of these unit characters. One may use as an example the various species of cattle. Cows of a certain breed may produce a very rich milk but not a great quantity. Cows from another breed may produce great quantities of less rich milk, while those of still another breed living in the tropics may be more or less immune to heat and tropical disease. If one wishes to bring cattle into a rather hot clime, it will, therefore, be to one's advantage to obtain that breed which will produce the greatest quantity of rich milk and likewise be able to withstand the great environmental change necessitated by removal from a temperate or cold clime to one of great heat.

We have already seen that the inheritable characters are contained within the chromosomes. The definite factors, whatever they may be, which carry the unit characters within the chromosomes, are called **genes.**

From our knowledge, at the present moment, of the way the chromosomes divide in cell division, and the way they throw off one-half of their number during maturation just before fertilization so that fertilization can again restore the regular number, we are led to believe that no unit character can be inherited unless a gene from the father and a gene from the mother unite in the chromosomes.

We may say, for example, that all the unit characters, which any individual can possibly inherit, are contained within the chromosomes of the germplasm of its parents; that each chromosome may contain thousands of genes which may occur in any combination, the individual himself actually inheriting only those unit characters which happen to be the result of the particular gene of paternal and maternal chromosomes which met at the time of fertilization.

To make this clear let us assume that a white and black guinea pig are mated. The whiteness and blackness that we see, lie, of course, in the somatoplasm; but, in order that either color be inherited, there must be genes in the chromosomes of the germplasm which determine the somatic character of whiteness and blackness. We know that, if a black guinea pig is mated with another black guinea pig, both of which are in turn the offspring of an entire race of black animals, that only black guinea pigs will be produced. However, if a black and white animal mate, the offspring are really **half-breeds** in regard to their germ-cells, though their somatoplasm may show some variation in color. We, therefore, assume, from the experimental evidence obtained through breeding experiments of many kinds, that in order to produce a black animal, both the paternal and maternal genes, which carry the determination of color, must have carried blackness. In the production of a half-breed, one of the genes determining color must carry whiteness and the other blackness. (Fig. 82.)

In other words, two genes always meet to produce any character sufficiently powerful to be carried on, in turn, through succeeding generations. The character which is thus carried on and which shows itself in the somatoplasm is called **dominant.** Blackness would thus be dominant when a white and black animal mate and produce half-breeds which are all black in color. However, as has already been stated, the color is only in the somatoplasm. It is important to remember that the germplasm remains **pure**; that is, some of the eggs in the mother and some of the sperm in the father will be of the black variety, and others will be of the white variety. To put this in other words, **there will be no half-breed eggs or sperm.**

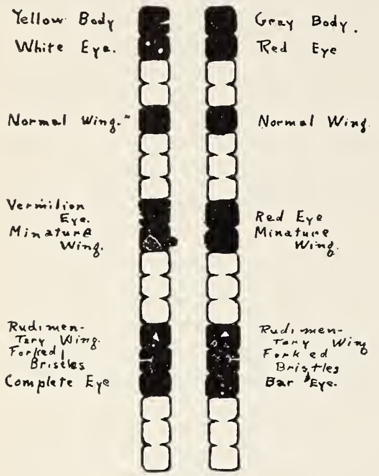

Fig. 82.

Diagram of two chromosomes, each square representing a gene.
An insect, for example, with these two chromosomes would possess a normal wing, a miniature wing, a rudimentary wing, and forked bristles. All these characters could be transmitted to the offspring. The insects' body and eyes, however, would be heterozygous.

Whatever unit character shows up in the somatoplasm in animals of different breeds, is said to be **dominant,** while that unit character, which **is present** in the germplasm **but is not seen** in the somatoplasm, is said to be **recessive.**

In our example of the mating of a white and black guinea pig, the offspring, though black, have whiteness in their germplasm even if it does not show externally in the somatoplasm. Blackness in this case is, therefore, dominant; whiteness, recessive.

In their accounts of breeding experiments, geneticists use a formula to represent dominant and recessive genes. The capital letter represents the dominant gene and the small letter the recessive. In the example we have been discussing, the capital letter—B—will represent the gene which carries blackness, the dominant color; and the small letter—w—will represent the gene carrying the recessive white. The formula in our example of a half-breed black and white, therefore, is—Bw—.

In those cases where pure blooded blacks would meet with pure blooded blacks, the formula would be BB, while in the breeding of two pure whites, the formula would be WW. It will, therefore, be noted that we may have the various formulas BB, Bw, WW, Wb, provided, of course, that a recessive black could be found.

Wherever two genes are alike, so that either has BB, or WW, the resultant zygote is called a **homozygote,** while the organism resulting from a homozygote is said to be **homozygous.** If the two genes of the mating pair are different, such as Bw or Wb, the zygote is called a **heterozygote,** the resultant animal being called **heterozygous.** It is, of course, quite common for the same animal to be homozygous for some characters and heterozygous for others.

The parents are often represented by the capital letter P. The first generation (which means the offspring from these parents) are represented by the formula, F_1. The offspring of F_1 in turn are known as F_2, and so on, the F representing a filial generation.

In many cases the various characteristics, which the genes determine, may be independent of each other; but, just as certain chemical elements have an affinity for each other, so there are various types of characters that often link themselves in the same way. This is known as **linkage.** Color of hair and the direction in which the hair grows, such as curliness, straightness, or whorls, are often linked. Then there are also certain types of **sex linkage** by which we mean that there are certain characters, such as plumage in fowls and eye-color in flies, which are almost always concomitant with the sex of the individual.

Much has been written on sex-determination in the past, though it is only recently that any progress has actually been made in this field. It has been found that sperm cells possess an extra or **accessory chromosome** (called an **X-chromosome** by American writers, and a **heterotropic chromosome** by Europeans). (Fig. 30, A.) When such a sperm cell fertilizes an egg, a male is produced, while, when an egg containing the regular even number of chromosomes is fertilized by a sperm with an even number of chromosomes, a female is produced.

Interpreting these findings of the cytologists, biologists now believe that there is such an extra chromosome in both egg and sperm, but that in the egg, this **X-chromosome** divides as do the others, although this division is delayed until some time after the other chromosomes have divided in the maturation divisions. This means that the **X-chromosome** of the sperm is really a **double chromosome** which fails to separate during spermatogenesis and consequently goes over to one of the two sperm-cells entire.

Then, in some organisms this **X-chromosome** has actually been seen to be made up of a larger and a smaller portion, while in the female of the same species both parts of the chromosome are of equal size. When the accessory chromosome is thus divided into two parts of different sizes, the smaller is called the **Y-chromosome.**

It follows from this that, if unit characters are carried by the genes of the **X-chromosome,** all organisms in which the sperm carry an **X-chromosome,** must necessarily transmit the characters of the **X-chromosome** to the female offspring only, while females can transmit them equally to all offspring. Similarly in those organisms in which eggs may lack one chromosome, the female can transmit characters only to their sons, while males can transmit to their offspring of both sexes. This is the explanation of sex-linked transmission as shown in men who are color-blind. Such men transmit this defect to their daughters, and the daughters can in turn transmit it to all their sons and daughters.

There are exceptions to this. A usual sex-linked characteristic such as color-blindness, is sometimes transmitted from father to son directly. This is explained by Bridges as being due to what he terms a "non-disjunction" of the sex-chromosomes in the polar divisions of the egg during the maturation division. In other words, such a non-disjunction may come about by the two **X-chromosomes** in the egg pairing but then failing to separate, so that either both remain in the mature egg or both are extruded with the polar bodies.

In a study of **parthenogenesis** (virgin-birth) further evidence is brought forth in regard to the function of the X-chromosome. For example, there may be one maturation division without a reduction of chromosomes. In this case the single polar-body and the egg nucleus will both contain the diploid number of chromosomes. This is quite common in the **Crustacea** and a few other forms.

Or, there may be two polar divisions, after which one of the polar bodies reunites with the egg nucleus. Here, again, the full number (diploid number) of chromosomes is found.

Or, in some forms (**Hymenoptera** and the male-producing eggs of **Rotifers**), two polar divisions really take place, which reduce the chromosomes to the haploid number. If these eggs are unfertilized, **they give rise to males.** Such eggs already have only half the full number of chromosomes. Consequently in their germ cells, in turn, there is no further reduction. The first spermatocyte division in these is really suppressed. If the eggs are **fertilized, they produce females.**

In those **Hymenoptera** where there are two divisions, but the chromosomes divide at the equator and not longitudinally, the diploid number is retained, and females are usually produced.

Various other evidences of great value and interest will be found in the books on Cytology mentioned at the end of this chapter.

The diagram of the chromosome-cycle of **Phyllaphis coweni** (Fig. 83) will throw light on this subject.

The top group shows a fertilized egg with four ordinary chromosomes and two X-chromosomes. Three lines of descent pass downward from the egg. On the left, this line of descent leads to a female which will produce a sexual egg. The central line of descent leads to a female which will reproduce parthenogenetically, and on the right the line of descent leads to a male.

The second and third groupings from the top represent the metaphase groups as well as the diagrammatic anaphases of three eggs, of which the left and middle will produce females, the right a male. In the female-producing eggs, the **X-chromosomes** divide at the equator and not longitudinally; while in the male-producing eggs they pair and separate so that the male has only one **X-chromosome.**

The fifth grouping from the top at the left, is the metaphase group of the first polar division of the sexual egg. All the chromosomes are paired. Below this, the anaphase of the first, and the telophase of the second polar division, leave three chromosomes in the egg.

The fifth grouping on the right is the metaphase group of the first spermatocyte division with paired regular chromosomes and a single

X-chromosome. Below this, the diagrams of the first (unequal) and the second (equal) spermatocyte divisions, leading to the ultimate sperm-cell with three chromosomes and a small degenerate cell with two. When the egg and sperm again unite in fertilization, the original six chromosomes are restored, and the egg is again as we see it at the top.

From what has been said, it can be plainly seen that in all organ-

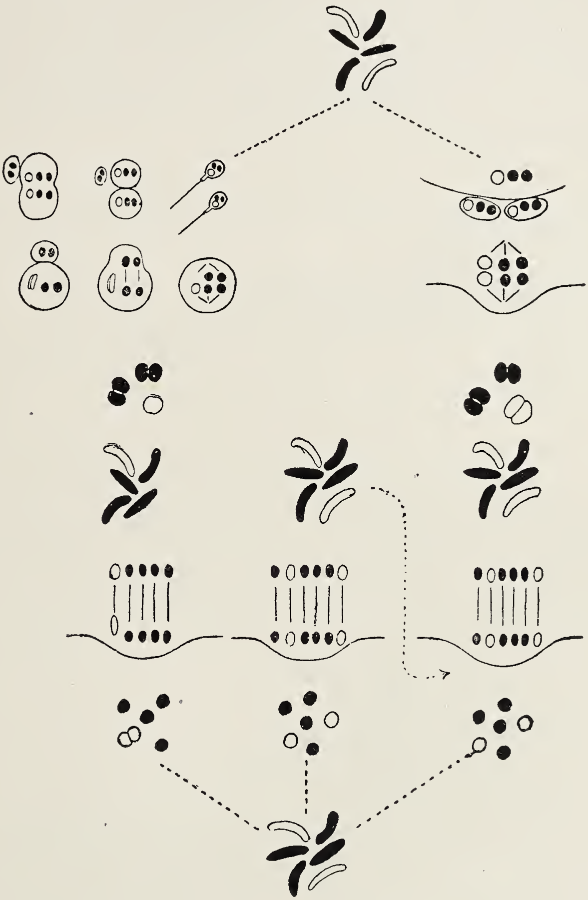

Fig. 83.

Diagram of chromosome-cycle of *Phyllaphis coweni*. See text for explanation. (After Doncaster.)

isms where there is an **X-chromosome**, this extra particle (as it does not divide as do the other chromosomes) must result in some sperm-cells having an even number of chromosomes and others an odd number.

For example, let us say there are twenty-one chromosomes in the original germ-cell from which the sperm is to develop. One of the newly forming sperm would possess ten and the other eleven chromosomes. The regular somatic number of chromosomes in such an organism would be twenty-two. The egg will, therefore, regularly divide and throw off eleven to obtain the haploid number. Those eggs, which are then fertilized by a sperm containing ten chromosomes, become males (as the diploid number in such a case would again be twenty-one) and those eggs fertilized by a sperm containing eleven would possess the full somatic number of twenty-two chromosomes and become a female.

This means that in those cases where there are **X-chromosomes,** the odd chromosome never pairs in the maturation division with another chromosome, nor does it produce a tetrad. It simply passes undivided to the daughter sperm.

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CHAPTER XII

ANIMAL PSYCHOLOGY

IN no branch of study is the student confronted with more difficulties in the way of separating fact from interpretation, and explanation from description, than in the field of Animal Psychology, and this, notwithstanding the fact that Animal Psychology owes its entire value to its ability to explain and not to describe.

The tendency of the human mind to read into an animal's actions the same motives and reasons that cause man to react in a similar manner is difficult to overcome. In fact, a definite word, **anthropomorphism,** is in common use among psychologists to describe just this tendency to humanize animals.

Still, the only way we have of interpreting the behavior of an animal must be in terms of human understanding, for we have neither language nor imagery which can bring to us the sensations, emotions, and driving force of an organism so totally unlike ourselves as an insect, for example.

As one writer has said, anger with us is always associated with an increase in heart beat and a more rapid breathing, and our nerves are all "set on edge," but an insect has a totally different set of blood-vessels, an entirely different breathing apparatus and a different nervous system. What are its accompanying sensations when it feels angry? In fact, a wasp often bites off its own abdomen when angry. How can we, when our respective organisms are so unlike, know much about how such animals feel?

Further, all of us have observed that probably most plays and novels hinge their plot entirely on some misunderstanding. If human beings, who have a common language to make themselves understood, are so frequently misunderstood, how much more will we not misunderstand and misread the actions of animals entirely unable to tell us anything in terms which are understandable to both?

It is for reasons of this kind that many throw up their hands in despair and insist that we never can know anything at all about the animal mind, but that if we wish to establish an animal psychology anyway, there is only one way to go about it, and that is, merely to study the behavior in the laboratory under set conditions so that we can learn just how each animal reacts to a given stimulus. Such a method assumes that all animals of the same sex, of the same age, and in the same state of health, will always react in exactly the same way when the same stimulus is applied under the same conditions.

We shall go on from this point a little later, after the student understands several important terms.

Objective and **Subjective** are two of the most important terms used in psychology. The former is the term applied to all things which come under the senses. That is, a thing is objective when it can be observed and measured in the laboratory. It is anything, in other words, which occupies space. Subjective refers to those things which make no observable difference in space and which cannot, therefore, be measured in terms of the rule and scale of the laboratory. For example, changes in the mental world, such as thought and feeling, are subjective. In the classic sense, **subjective means the act of the mind itself or what is in the mind,** while **objective refers to the matter with which the mind works.**

An illustration of these two terms, as they are commonly used, comes to mind. Suppose a neurologist were to examine the optic nerve and the optic centers of the brain of a student while the latter is reading a letter. The neurologist could probably tell that the optic nerve and center were functioning, but he could never tell what the letter contained, nor could he see what emotions were called forth in the mind of the student. The movement in the nerve and nerve center would be objective, while the emotional impression made on the student would be subjective.

Not only would the neurologist be unable to observe the emotional impression made upon the student, but he would be unable to tell why certain vibrations which, so far as observation goes, are all alike, should produce sensations of red or green in one case, and another color in another case.

All our emotions, longings, ambitions, thoughts, and ideas, so long as they remain mental states, are subjective, while when they express themselves as acts, they become objective.

Psychology is the study of the subjective world. The word Psychology (Greek psyche=soul+logos=discourse) actually means the study of the **soul,** but since laboratory methods have come into existence in psychology, and laboratory men think only in terms of measurable substances, it is commonly said to be the study of **mental phenomena.**

Since the laboratory methods of studying everything objectively under set conditions has made its way into psychology, the workers in this field have become divided into various camps or schools. First, come the **Behaviorists,** who insist that the **results** of mental activity are **actions and reactions to given stimuli,** and it is only these results which can be measured, and which, therefore, may validly be used as data on which to form any theories of the mental life of animals. Second, come the **Introspectionists,** who follow the classic method of antiquity. They insist that the only real way of studying mental life is **to introspect**—to look into our own mental life and try to understand how and why we do what we do under varying conditions. They insist that we must analyze our own thoughts, motives, and emotions, and then, if an animal has an organization quite like our own, we may validly assume that it, too, functions somewhat like our own.

Since extremists on any side of a discussion are likely to go astray, it is always best not to follow entirely any single group to the exclusion of another. To be fair, one must use anything and everything that will throw light on the problem one is trying to solve.

The word **Mind** is another confusing term. By the older writers it was used to designate the **personality** of an individual. That is, if one say with Descartes, "I think" therefore "I exist," the "I" which does the thinking and which does exist is the true personality, the true mind. Or, one may note that it is quite common to dream that one has died and attends one's own funeral. That which can look at its own physical body as the physical co-partner of the true ego—of the individual's personality—is the **mind,** or as the older writers called it—the **soul.**

Not only do we here see a distinction of the ego, or personality proper, as **mind,** but we also note that the mind is separate from the thoughts which the mind brings forth. We can, therefore, understand these writers when they tell us that the brain is in turn the organ of the mind, but not the mind itself.

The average laboratory man will have little of this, however. He insists that mind does not exist as distinct from thought and emotion. He means by mind the whole **"stream of consciousness"** of the individual—all thoughts such as one has ever had, plus all one's emotions, such as pleasures and pains—**accumulated experiences of the individual,** in other words.

The laboratory men do, however, admit two divisions of this mental life, namely, **consciousness** (awareness) and **feelings** (emotions or affections, such as pleasure and pain).

The student can understand these two divisions easily if he will think of breaking a bone in his body. It is one thing **to know** (be conscious of) that the bone is broken, and another thing entirely to **feel** the pain it may cause.

The idea of a difference between the mind and the physical body containing it, leads us to note the distinction between **mind and matter.** Those who accept this distinction are called **dualists.**

Great conflicts have been waged by the learned of all times as to which is the more important of the two—mind or matter—and which was first upon the scene of existence. Some have contended that mind (spirit) came first, and this, then, was the cause of the physical universe (matter). Such contenders are known in philosophy as **spiritualists.** Others contended that matter was first on the scene, and that mind was late in its arrival, because it is only an emanation of some kind from the physical. That is, mind is something like the secretions from ductless glands which we know little about, but which we do know exist. Such men are called **materialists.** Yet another group insisted that as mind and matter are always together, neither may be given the preference. Both are different sides of the same coin. Each thought-wave is always associated with a nerve-wave of some kind, and neither can exist without the other. Such men are called **monists.** It will be seen that the term "monists" is applied to this group because they do not accept a dualism in life.

These different groups of contenders attack psychological problems with different prepossessions. The spiritualist is likely to call himself an **interactionist** in psychology, the materialist a **behaviorist,** and the monist a **parallelist.**

As it makes a profound difference to a patient which one of these theories his physician holds, the student must know what each term means, or he will be totally unable to pass judgment on the many and conflicting discussions which are ever coming before him.

The interactionist holds that the state of mind of an individual can and does influence his physical being and **vice versa.** An example of this is a man worrying over financial losses, whose body becomes run down until disease clutches him.

The behaviorist insists that only a definite physical reaction, measurable in the laboratory, is valid data on which to base a scientific conclusion, and that until the individual mentioned above shows a definite measurable reaction, there is no change which we as scientists can use or accept.

The parallelist, insisting as he does that both the mentality and the physical organ which is associated with it, are different sides of the same thing, must necessarily consistently claim that the mind is totally unable to influence the body and the body totally unable to influence the mind. In fact, one prominent parallelist says that one may as well expect a piece of beefsteak put into a sausage machine to come out a moonlight sonata as to expect either body or mind to influence each other.

It is, therefore, only the interactionist who can consistently speak of **nervous and mental** diseases, and who can consistently use both physical and psychic remedies.

At this point we may consider what is commonly designated as **structural** and **functional** psychology.

Structural psychology concerns itself with (1) the general organization of an organism, (2) the general organization of its nervous system, and (3) the organization of the specialized nerve parts, such as the eye, ear, nose, etc.

Functional psychology is interested in (1) the general way an organism reacts (discrimination), (2) whether the organism can modify its action (docility), and (3) in how many ways and in what way its behavior will vary (initiative).

Again the student must be cautioned not to let one side of a problem cause him to discard much that is of value in opposing schools of thought.

Just as those who are primarily interested in nothing but anatomy, are likely to leave out important functional causes in a disease, so those primarily interested in physiology are likley to forget the structural elements which may contribute points of tremendous importance.

All schools of science have been drilling into the student the supposed "fact" that "structure determines function," but since the very recent work of Carey, who converted unstriated bladder-muscle of a living dog into living heart-muscle by simulating heart conditions in the bladder, we must insist that function has just as important a part in changing and determining structure as structure has in determining function.

However, we must not forget that even in the case just mentioned, the substance to be changed was already present and must have possessed the potentiality of change before it could be worked upon.

With this introduction we can the better understand the two ways in which the study of comparative psychology is approached by the modern laboratory worker. **First,** we may take a highly developed individual, such as man, and after analyzing his mental world, apply the knowledge thus gained to the lower forms, or

Second, we may follow up, step by step, the increasing learning-ability on the part of all phyla of animals, beginning with the unicellular and passing upward through an ever-increasing scale of ability.

It is this second method which seems to have found most favor with animal psychologists.

But, in reading works on animal psychology, one is always confronted with a great confusion of terms. In fact, one finds here the same difficulties that confront the student in any of the biological sciences. The first workers in all these fields were philosophers, and were interested primarily, and sometimes only, in the human family. The terms, therefore, which these men used, although worked out with great precision, applied only to man.

The newer writers took many of the older labels and placed them on new bottles, so to speak. This has caused a world of confusion, not only to new students, but to many well versed in language and literature.

Such words as Mind, Intelligence, Reason, Memory, Consciousness, Sensory or Associative Memory, Instincts, and Reflex Actions, are some of the terms which the student must use, and which have many conflicting meanings in modern literature. It is imperative that the student obtain a clear and concise definition of these terms and use them only in this restricted sense. Then only can he understand the meaning which different writers assign these words, and then only can he know whether they are calling other things by the same name, or giving different names to the same thing.

We shall have to speak of **Instincts** immediately, so it is well to begin with this term. **Instincts** are defined as **inherited tendencies in**

an organism which cause protective reactions when harmful stimuli are applied. For example, a frog, even after both cerebral hemispheres are removed, will still scratch the part of its body to which a drop of acid is applied, and it will even snap at and swallow a fly which has been placed on the tip of its nose. Again, a fly will walk, fly, and clean its legs and wings, after its head is entirely removed, and the writer has kept a decapitated cat alive for many hours by artificial respiration and caused it to perform many instinctive actions such as scratching itself, waving its tail, etc.

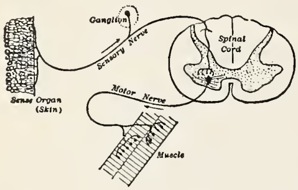

Fig. 84. Diagram of the path of a simple nervous reflex action.

In order to understand Reflex Action, it is first necessary to know the meaning of a **Nerve Arc** (Fig. 84). This latter is merely the entire nerve-path over which an impulse passes to a nerve-center and out again to a muscle cell. It must, therefore, consist of the nerve-ending of a sensory nerve (receptor) through which the impulse is received, and the sensory nerve-fiber which carries the impulse to the nerve-center to join at this point with a motor-nerve fiber which in turn carries the motor impulse to the **motor-nerve-ending** (affector). This motor-nerve-ending is always located in some muscle fiber. Psychology textbooks often speak of a nerve-arc, as **"a perception with a motor impulse."**

A **Simple Reflex Action** is one that passes over such a simple nerve-arc without first passing to the higher nerve-centers, or, we may say, one which does not come into the **consciousness** of the individual in whom the action takes place. Such a reflex action is, therefore, purely physical. There is no need of assuming any mental state or sensation as an accompaniment.

When an individual is born, his nerve **arcs are** set in some form or another, so that with one individual the same stimulus will cause quite a different reaction, than it will in another. But, just because these nerve-arcs are **set** in the way they are, the same nerve-arc will always react in the same way to the same stimulus, if all other conditions are equal. For example, a child may have grown accustomed to saying "I is" for "I am" and have said it so often that it finds it very difficult to correct itself. Now, if we constantly force the child to use the form "I am," the particular nerve-arc which carried the "I am" reaction will become relatively stronger than the one which carried the reaction "I is," and then, and not until then, does the latter phrase become a sort of second nature to the child.

So, too, a puppy that has the vicious habit of snapping at passers-by, can be made to react differently by giving him a whipping several times, immediately after he does the undesirable act.

In both these cases memory enters, but only a simple **sensory memory (association memory)** which has little to do with any **thought.** The impulse (inner stimulus) in the puppy to snap, is great, and so the "snapping nerve-arc" carries the impulse and the snapping is done; but the punishment, which has been meted out, has set up **an impulse of an opposing nature,** and as soon as this latter becomes the stronger impulse, the puppy has been **trained.**

We may say in this case, that the puppy has the desire to snap, and the nerve-arc, which carries this snapping-impulse, begins to function. But the whipping has caused a new nerve-arc to function at the same moment, so that a third nerve-arc, that of **inhibition,** comes into play and the animal does nothing. This is quite similar to the reaction of persons in hypnosis. Here an individual is told he cannot bend his arm. The impulse not to bend the arm is just as strong as the one to bend it, so no movement takes place.

An **impulse** is defined as an **inner stimulus.**

It is well to bear in mind the foregoing paragraphs as these show the possibility of two opposing impulses and even two opposing reactions taking place at one and the same time over different nerve-arcs. Often we read of lower organisms possessing discriminating powers of various kinds which can be interpreted in quite different ways from what the writer of such an account would have us believe. We need only remember that there can easily be one set of nerve-arcs functioning for the acceptance of food and another set for the rejection of it, so that it depends on which set carries the stronger impulse as to whether the animal accepts or rejects the food. It is by no means necessary to assume any **discriminating ability.**

There are also **Complex Reflex Actions** making use of several nerve-arcs, sometimes often forming regular chains of reactions. In these cases, the result of one stimulus sets up another, and so on. In fact, we call such continued setting up of stimuli **reflex chains.** As an example we may refer back to the frog whose cerebral hemispheres have been removed. If we place a fly on the tip of its nose, that stimulus sets the "snapping" nerve-arc functioning. Then as the fly is taken into the mouth, a new nerve-arc causes a swallowing impulse, which sets up reactions of still other nerve-arcs which in turn cause the digestive glands to pour out digestive substances.

It will be noted that such reflexes are quite **useful** to the animal, and it will be remembered that our definition of instinct called attention to the **protective** value of inherited nerve-arc actions.

Instincts may be **deferred.** That is, they may not be observable at birth, but come forth only later in life when various glands begin to pour out secretions which affect many parts of the body.

It is often stated that instincts are the "inherited habits" of the individual's ancestors. This was Lamarck's idea. But this cannot be, because many animals lay their eggs before they themselves have developed the later characters, which the offspring possess. Consequently, the young would have to inherit a habit that the parent was going to form later. This is somewhat like saying that because a mother is divorced, her daughter inherits a desire for divorce from her mother, which, therefore, resulted in the daughter also obtaining a divorce.

While instincts are made up of reflexes, the reflex proper is said to affect only one part of the organism, while instinct affects the entire body. That is, we should say the winking of the eye, when danger threatens, is **reflex**, while running away from the danger is **instinctive.**

Instincts really consist of inner driving forces which make the animal possessing them restless until the instinctive act is performed. However, we must remember here also that just as with the impulses already mentioned, there may be conflicting instincts. In such cases the stronger will come forth. Or both may be equally strong, so that no action at all will take place.

Recent psychology often speaks of **tropisms.**[1] As we have seen from our study of former chapters, a tropism is a movement of some kind on the part of a living organism. Those who wish to interpret all action of living organisms in terms of physics and chemistry are fond of using this term. Such men prefer to cast the term "instinct" to the four winds of heaven and explain everything in **physico-chemical terms.** They insist that a caterpillar climbs to the end of a twig on account of the chemical change in its body that is caused by hunger, let us say. New chemical molecules and adjustments are forming, and this makes one part of the body lighter than another, so that the laws of physics enter and the heavier part will be followed by the lighter in going downward, or a chemical affinity of some nature will draw the chemical substance of the animal toward it. After having eaten the tiny bud on the twig, a new chemical change takes place and so the animal must, whether it will or not, obey the next chemical and physical change and descend from the twig.

Dr. Vernon Kellogg, recently in this connection, called attention to a scientific friend who explained to Dr. Kellogg that the reason he took a corner seat in a restaurant was due to a primeval impulse which made him want to have his body in close contact with the wall. But, as Dr. Kellogg says, the reason he chose that particular seat was because he had made an appointment to meet a friend there.

As the principal test of an animal's mental ability is the rapidity with which it **learns,** we must know what learning means. **Learning** means the ability on the part of a living organism to vary its actions according to some definite plan which will show that it has profited by past experience.

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[1]*Tropisms* really mean growth reactions and taxis mean movement, but most writers use *tropism* to include *taxis.*

In this connection one is also confronted with difficulties as in other fields. Suppose one is attempting to see whether an animal can distinguish between colors and then learn to go toward one hue rather than another. Suppose now, that the ainmal does not show any more inclination of going toward one color than toward another. This by no means proves that the animal cannot distinguish, or is unable to learn, that there are two colors. It may mean nothing more than that colors make so little difference to the animal that there is no reason (motive) for his choosing one rather than the other. In such an instance the animal's reaction to both colors would be identical, and one could prove little or nothing from its behavior.

Another animal may be thought unable to learn because it tries a problem a few times and then ceases to react at all to the stimulus. This may be due entirely to fatigue on the part of the organs used, and not to inability to learn. That is, the nerve receptors may become dulled or tired by new stimuli which are foreign to the animal in its native career.

Or again, some sensation may be pleasant to an animal only if secondary factors are present, such as the taking of food only when it is hungry or when the body is in good health. But surely the rejection of food does not mean that the animal either can or cannot discriminate between foods. We often will not eat one kind of food, while another is relished, or we often will just as readily eat ice cream, candy, or fruit, and show just as much desire for the one as for the other; but this certainly does not mean that we do not know the difference between these three types of edibles.

Then, too, the state of health makes a tremendous difference in what an animal will choose. Dogs and cats eat certain plants at certain times, but at other times they will not touch these foods. But do they not know the difference between these plants and other food?

Then, too, an animal may be trained to do certain things, but suppose it does these things without having been trained. Can one not argue as well that the animal merely stumbled upon doing the act, and then doing it often, the nerve-arcs became **fixed** and the animal can no longer help itself? It is now a **habit**.

Habits are but acts performed by fixed nerve-arcs.

The question may arise as to what difference there would be between psychology and physiology if all we are to study consists of nerves and reactions. Really, there would be no difference **in content** of the two sciences, the difference would consist in **emphasis**. The psychologist lays stress on emotions, feelings, etc., and the physiologist on the simple observable reaction which follow a given stimulus. The psychologist, in other words, wants to know how the animal feels and what it has in its consciousness when a stimulus is applied and its actions are changed.

We have seen in our study of past chapters that the unicellular **Paramoecium** has only two simple reactions, namely, a backward and forward movement, while the vertebrate frog can move in many and varying ways in order to get out of harm's way. Probably all animals can **learn.** That is, they can be taught to make some change in their behavior, but the rate of speed with which they can learn probably becomes greater as we ascend from lower to higher phyla. The same may be said of the complexity of the problems to be learned.

When left to themselves, all animals and children learn whatever they do learn by what is called the **trial-and-error** method. This simply means that they try something and, if this something is unpleasant or painful, they try something else. Contrariwise, if a reaction produces pleasure, it is done again and again until it becomes a habit.

All learning, no matter what it may be, **must, however, be based on instinct** in its widest sense. That is, the problem presented must be something which can be solved by making use of some instinctive behavior of the animal upon which we wish to experiment. For example, a cat can be placed in a closed box in which there is a lever, which, when pressed, will open a door. Now, cats are excitable and, when excited, will begin to leap about. This is an instinctive action. If, while leaping about, the animal strikes the lever and the door opens, it can be trained, by enclosing it often enough in the same or a similar box, to press the lever without going through the leaping first.

Learning, then, really means **profiting by past experience.** But no profiting by past experience is possible unless such past experience is remembered. Now, such memory by no means must be a definite thinking out of a past event and then sitting back and saying "I will" or "I will not do this again." Most physical experiences, even in man, are merely non-conscious functioning of nerve-arcs. Neither men nor the lower animals do any **thinking** in regard to these simple or complex-chain-reflex actions. It is a mere association of one stimulus starting another and is called, as already stated, **sensory**, or **associative memory.**

There may, or may not, be **an awareness** of doing an act, plus **an** associated pleasure or pain sensation. That is, there may be consciousness not only of the fact that an act is being performed, but there may also be an awareness of pleasure and pain, accompanying it, though there is little proof that a **definite thought**—that is, **reasoning**—is performed, and that it is then due to such reasoning that changes of action are made. These learning acts are in all probability due only to sensory memory.

An example comes to mind. We have all heard some one tell of a horse that knows when Sunday comes, that being the only day when the animal does not come out of the stable to be harnessed as soon as its master appears.

But does this show that the horse can count up to seven and has a sort of mental calendar on which he checks off the days? By no means! All it may mean is that if a horse works six days in the week, there is a certain feeling of tiredness which has become associated with that amount of work, just as a blind man can tell by his "feeling" how many blocks he walked and when it is time to turn without counting the blocks.

We may then conclude that all animals may be conscious to some extent; that is, they may be **aware** of their actions, although this has nothing to do with reasoning—with thinking.

That veteran experimental psychologist, the late Professor William Wundt, said, "Animals never think and human but seldom," and most animal psychologists hold to this dictum, if, by "reason" is meant **true thinking**, that is, **a weighing of two or more sides of a problem and then by a definite mental act coming to a decision or conclusion as to what is to be done.** In other words, thinking means to use **abstract ideas** and to **form conclusions.**

There are many writers who mean by the term "thinking" only an ability to profit by past experience, so we must always find what a writer means by his terms before we attempt to pass judgment on what he says. Others likewise speak of "intelligence", which **should mean** only the ability to think, as any associative memory. This is really placing old labels on new bottles and is very confusing to the student who wishes to know both the past and the present of a branch of science.

The desires of the different men in animal psychology must also be taken into consideration when reading their respective works. There are those who wish to show that there is no real difference between man and the lower animals. These insist that man has nothing distinct from the lower animals except an articulate language, but that man's seeming difference in the mental world is only a little greater development of animal characteristics. Language by them is often said to be the cause of man's greater mental ability in that he can by this means write down his findings so that others may profit by them.

Those who hold that man is something separate and distinct from the animal, call attention to the fact that language but expresses thought, and one must have thought before he can develop a language, rather than language being the cause of thought. These men also insist that there is no proof that any animal has ever "reasoned" out a problem in the way mentioned in an earlier paragraph, and therefore no animal lower than man can be said to have any "intelligence" in the classic sense.

These latter men would say that hundreds of thousands of cats, dogs, and even apes (which are considered the more intelligent animals) are very fond of warm places. Such animals have lain before hundreds of thousands of open fires and enjoyed the warmth. They have seen their masters keep the fire aglow by placing fuel upon it, and yet not in a single instance has any animal drawn the very simple conclusion that it is the fuel which keeps the fire going, and has, therefore, placed (without being taught), a single stick of wood on the dying embers.

Not only this, but the child, when it grows up, teaches others, and our schools and colleges are all arranged for the sole purpose of making a young man and woman at an early age know what it would take a very old person centuries to learn by personal experience. No animal is known to teach another a trick which it itself has learned from a third individual, unless, of course, the act is instinctive and would have been learned anyway.

Whether one thinks of man as but a more highly developed lower animal, or whether one looks at man as a being apart, all agree that man can reason, whether he often does or not. All agree that man has larger brain-hemispheres of finer texture than organisms on a lower scale; that he has an upright posture and a more delicate hand; that he can use tools, and has the foresight to be able to raise his own food and to live in cold climes by understanding the use of fire; and above all, that he is set apart from other creatures not only in having an articulate language, but also in having a knowledge of what he should and should not do—in other words, that he has a **moral sense**.

So, too, all are agreed that the **trial-and-error method** of learning shows infantile, or animal, intelligence and not human intelligence. All education, all colleges and universities have been brought into existence to present **principles**, that is, to present a mental and cultural gauge, so that each individual need not try out every detail of experience for himself; but, that he can, by learning the principles and laws which govern nature, sit back and "figure out" or "reason out" whether a given conclusion can or cannot be true.

This comparison is just as workable in the political and religious world as it is in the scientific. Here is shown the difference between the educated and the uneducated man. One must not feel hurt or surprised if an educated man, knowing his principles and his laws, laughs at one who proposes a problem or a solution of a problem which can immediately be seen to be erroneous. The uneducated man cannot understand or see this until it has been tried and found unworkable.

From what has been said in this chapter we must, if we wish to be sure that we are right, know what a writer means by his terms; we must be sure that we are not reading too much of our own thoughts into an animal's acts; we must be sure that we are consistent in our interpretations and that, if we explain an animal's behavior in terms of tropisms, we must also interpret man's in much the same way; we must insist that the observer who is attempting to convince us that his theories are correct, has a scientific training and can justly weigh all **matters** that make a distinguishing difference in our interpretations. That is, he must be able to separate fact from inference. We must insist that he be intimately acquainted with the habits of the animal he is discussing, so that he will not assume, for example, that an animal, like many insects, which have an instinctive impulse to cover up obstructions, is showing great intelligence when it covers up a minute stream and thus forms a bridge and crosses it. We must insist that he know the past experience of the particular animal he is discussing so that he will not confuse an associative memory with true intelligence. We must insist that he has no personal affection for the animal and thus wants to make it "show up" well. And lastly, we must insist that he do not let his desire to tell a good story gloss over important details and leave out others.

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CHAPTER XIII

INTERMEDIATE ORGANISMS

ONE of the interesting findings of Biology is that it is sometimes impossible to determine whether certain types of lower forms are plants or animals. The classic example of this is the plant-animal **Haematococcus** consisting of a single cell which moves about by means of flagella.

It will be remembered that **Euglena viridis** has chlorophyl in the body but is classified as an animal. One of the great and outstanding characteristics of plants is that most of them possess chlorophyl **if they grow in the light**, and that they are capable of manufacturing their own food by virtue of this fact. (See Chapter on the Chemistry of Living Matter.)

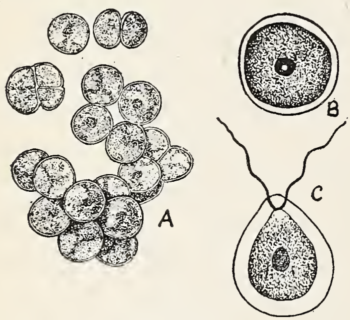

Fig. 85.

A. Pleurococcus.
B and C. Haematococcus Cells.
(Greatly magnified.)

Pleurococcus (Fig. 85), commonly studied in the laboratory, is a close relative of **Haematococcus.** It is a one-celled organism found commonly on the north side of trees, moist rocks, and wooden fences, dull green in color, and powdery when dry. When moist it becomes brighter in color and slimy to the touch. It is found in practically every part of the world on the shady and moist sides of the objects mentioned above.

Under the microscope it is found that this substance consists of thousands of tiny single-celled organisms to which the name of **Pleurococcus** has been given. There is a definite cell wall and a nucleus. The chloroplast, however, obstructs a view of the nucleus in the unprepared cell. The organism reproduces by simple fission and has a tendency to form clusters or colonies, usually of from two to ten or twelve cells. When this occurs, the cells assume a more or less irregular shape due to the pressure of the adjoining cells. The nucleus lies near the center of the cell and contains one or more nucleoli. The network of the nucleus can also be distinguished.

In the cytoplasm will be found the chlorophyl-bearing organ or region called the **chloroplast.** Due to the chlorophyl this will appear bright green, but, if the cell be placed in alcohol, the chlorophyl will be dissolved, leaving the chloroplast grayish. It is important to note the distinction between the chloroplast, which is a **living organ** of the **proto-**

plasm, and the **chlorophyl**, which **is simply the green pigment** contained in the chloroplast.

Photosynthesis.

In the final analysis, every particle of food, which an animal eats, must come from and through the plant world. For example, when one eats a piece of steak, the animal from which it was taken, lived either directly on plants or on other animals which fed on plant-life.

Here it is well to appreciate the interesting way nature has of keeping a sort of balanced quantity of all needed organisms; for the meat-eating animals or **carnivores** do not allow an overproduction of plant-eating animals or **herbivores**, and are prevented from multiplying too rapidly by parasites in their own ranks; while much of the vegetable world is saved because animals eat each other.

Consideration of these facts has led to the statement that the important thing in life is to get enough to eat and to prevent one's self from being eaten.

The plants manufacture their own food from the substances they can extract from the surrounding soil and the air. Plants are, therefore, not dependent upon other animals or plants for their food as animals are. Those organisms, dependent upon other living organisms for their food, are said to be **heterotrophic** (   ) in nutrition, while those, which can manufacture their own food, are said to be **autotrophic** (   ) in nutrition.

But only those plants, which possess chlorophyl, are autotrophic. Therefore, **fungi, molds**, and **most bacteria**, which **are plants**, but which **have no chlorophyl**, are **heterotrophic**; and, being obliged to live upon other organisms, they are parasitic (   ) or saprophytic (   ).

Chlorophyl is either contained **in a chloroplast**, as already stated, or, it is **scattered throughout** the protoplasm in the simpler green plants. Chemically, chlorophyl is a complex compound of carbon, hydrogen, oxygen, nitrogen, and magnesium; its probable empirical formula is given by one investigator as $C_{54}H_{72}O_6N_4Mg$. Iron, while not a constituent of chlorophyl, is, nevertheless, always present in the chloroplast and seems to be essential to chlorophyl formation. Either in solution or in the living plant, chlorophyl absorbs part of the light which falls upon it. The energy of the light thus absorbed by the chloroplast is the active agent which enables the plant to perform its work. As light is required, this process goes on only during the day.

The materials from which carbohydrate food is manufactured by green plants are carbon dioxide and water. Carbon dioxide is present in the atmosphere in the small but constant concentration of about 3 parts per 10,000 parts of air, and, therefore, readily available to such plants as **Pleurococcus.** "Water is absorbed directly from the substratum through the cell wall into the protoplast. The carbon dioxide taken in is dissolved in the water in which it is readily soluble. While the exact steps in the process of formation of carbohydrate foods from these substances are not yet clear, the essential facts are well established. The carbon dioxide and water are partially or completely reduced to their elements, which immediately recombine to form a monosaccharide sugar (probably dextrose) with the freeing of oxygen. These two processes are represented by the reaction $6CO_5+6H_2O=C_6H_{12}O_6+6O_2$. The oxygen is given off into the atmosphere through the cell wall. The sugar is the primary food of the plant, being the principal material used in the synthesis of other foods and in the processes of metabolism. When it is produced in excess of immediate requirements, a further reaction takes place by which some of the water is eliminated and the sugar is 'condensed' into starch. This reaction is $n(C_6H_{12}O_6)=(C_6H_{10}O_5)n+n(H_2O)$."

Starch is deposited in the chloroplast as granules, or "starch grains," which form a reserve food supply for the cell. Starch grains soon disappear in green plants kept in darkness only to reappear after the plant has again been in the light for a considerable period of time. In some plants, as in **Vaucheria** (Fig. 86), the excess food is stored in the form of a fat or oil, but it is probable that here, too, sugar is the first food formed.

The process by which carbohydrates are manufactured in green plants is called **photosynthesis.** Its essential features may be summarized as follows: "The materials used are carbon dioxide and water; the energy is obtained from sunlight a b s o r b e d by chlorophyl; the chloroplast by the

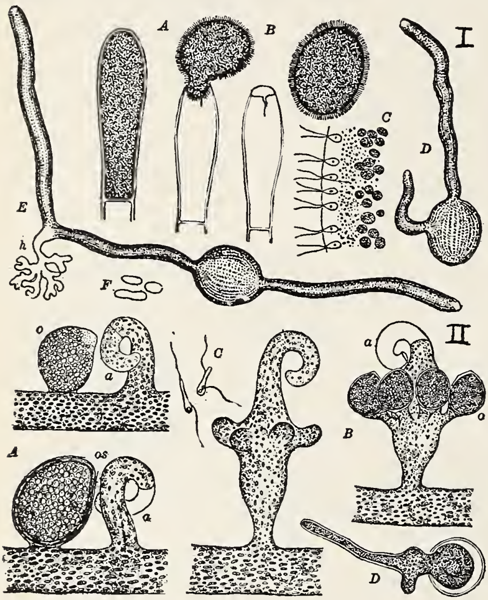

Fig. 86.
I. Asexual Reproduction of the Green Felt

(Vaucheria.)

A, formation and discharge of the large, many-ciliate zoöspore from the terminal sporangium; *B,* the zoöspore showing the ciliated surface; *C,* section through the surface of the zoöspore showing the pairs of cilia above the nuclei and the layer of plastids beneath; *D,* germination of zoöspore; *E,* young plant of *Vaucheria,* the two filaments having arisen at opposite ends of the zoöspore, one having developed an organ of attachment or holdfast *h; F,* a group of plastids, the lower in process of division. *(A, B,* after Götz; *C,* after Strasburger; *D, E,* after Sachs.)

II. Sexual Reproduction of the Green Felt *(Vaucheria.)*

A, Vaucheria sessilis; o, oögonium; *a,* antheridium; *os,* the thick-walled oöspore, and beside it an empty antheridium; *B, Vaucheria geminata,* a short lateral branch developing a cluster of oögonia and a later stage with mature oögonia *o* and empty antheridium a; *C,* sperms; *D,* germinating oöspore. (From Bergen & Davis "Principles of Botany" by permission of Ginn & Co., Publishers. *C,* after Woronin; *D,* after Sachs.)

use of this energy brings about a chemical synthesis of the materials, resulting in the freeing of oxygen and the production of a sugar, some of which is usually transformed into starch and stored in that form."

Some **mineral substances**, such as magnesium and iron, are also necessary for the plant to carry on its life-processes. Nitrogen, potassium, phosphorus, calcium, and sulphur are also required by most plants, although it is to be understood that there are very minute quantities of these in so simple a plant as **Pleurococcus.**

The process, by which proteins and fats are built up, is not known in detail, but it is supposed to be due to the action of enzymes. The fats occur in **Pleurococcus** at those times when the plants become dry, and are inactive or in a resting condition. At such times little or no starch is formed, while fats are present in quantity.

YEASTS

The **Pleurococcus** just studied, though a simple single-celled plant, is quite complex when compared with a yeast cell. The yeast cell is merely a small mass of granular cytoplasm with various vacuoles scattered about. These vacuoles must not be mistaken for nuclei. Often there are little **buds** (Fig. 87) on the side where a new cell is forming,

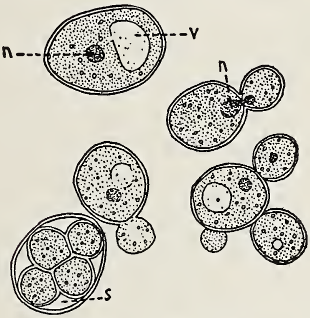

Fig. 87. Yeast Cells.
n, Nucleus; *v,* vacuole; *s,* ascus.

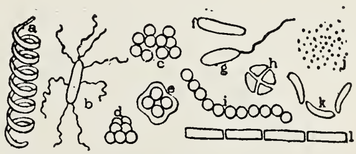

Fig. 88. Various Forms of Bacteria.

a, Spirillum; b, Bacillus typhosus; c, Staphylococcus; d, e, j, h, Micrococcus; f, k, l, Bacillus; g, Psuedomonas pycocyanea; i, streptococcus. (From G. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Sons & Co., Publishers.)

and sometimes three or four cells will form within a single wall, in which case the outer wall forms an **ascus** ( ), and the cells contained therein are **ascospores.**

The nucleus may be shown by special staining processes.

Yeasts have been called **organized ferments** because fermentation is actually associated with the life of the yeast-cell. That is, there are enzymes **within** the cell (intracellular) which **act through the living protoplasm** which produced them. They are not poured out as in the saliva or the pepsin (extracellular).

This power of producing fermentation, possessed by yeasts, is still retained even though the plant itself be killed with alcohol, ether, or acetone So. too, the bacteria, which cause lactic acid in milk, may be apparently killed, thus losing their power to perform any of the normal vital actions such as growing and dividing, and yet be able to produce lactic acid.

Yeast reproduces **by budding,** also called **gemmation** ( ).

A valuable study by the great French bacteriologist, **Louis Pasteur,** has shown that various inorganic substances could be made into a fluid, and, if yeast cells were placed therein, they could utilize it for growth and reproductive purposes. This ability to use and manufacture new substances from **wholly inorganic** matter sets the yeasts apart as being a sort of intermediate grouping between even the lowest plants and the inorganic world.

Yeasts must have oxygen, however, to carry on their work. The **anaerobic** ( ) bacteria are the only exception among living organisms in not needing oxygen.

It must be remembered that the yeast cell is an organism and is already existent, only making use of these inorganic substances by converting them into proteins and carbohydrates, by virtue of the chemical enzymes within the yeast cell itself.

Yeasts work at temperatures from 9° to 60° C. When fermentation takes place, as in bread, the temperature is raised during the fermentation process by the release of energy.

Yeast secretes an enzyme which is a sugar ferment. This enzyme may, for example, convert starch into sugar, although yeast "utilizes only about one per cent of the sugar, and decomposes the remainder into carbon dioxide and alcohol. The reaction of the fermentative decomposition may be expressed as follows:

Sugar		Alcohol		Carbon dioxide
$C_6H_{12}O_6$	$=$	$2C_2H_6O$	$+$	$2CO_2$

It is the production of these two by-products that makes yeast commercially important. Yeast produces the same reaction in the sugars of cider and wines, and in the metamorphosed starches of the cereal grains, which are chiefly used in industry in the production of alcohol. The carbon dioxide is also utilized in the making of bread. Yeast is mixed with the dough, and, fermenting in it, evolves the carbon dioxide gas, which "raises" it, making it porous and improving its digestibility and flavor.

An interesting experiment may be performed by placing a little fresh yeast in a bottle of Pasteur's solution (or even in a 15 per cent sugar solution made with tap water which will be likely to contain enough of the mineral salts for considerable growth). Keep this in a moderately warm place. Within twenty-four hours abundant growth will be evidenced by the increasing turbidity of the liquid, and by the taste of the alcohol in it as well as by the odor of the escaping carbon dioxide[1] arising from it.

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[1]A simple chemical test of the presence of CO_2 in the escaping gas may be made by thrusting a glass rod with a drop of lime water suspended on it into the mouth of the culture bottle. The calcium oxide (CaO), of which lime water is a solution, readily unites with free carbon dioxide to form a white precipitate of calcium carbonate $CaCO_3$ ($CaO+CO_2=CaCO_3$) which may be seen to form in the drop.

BACTERIA

It is common to hear discussions regarding **germs** of various kinds. Such discussions usually pertain to all those plants and animals which are likely **to cause disease. Bacteria,** however, refer to very minute **plant organisms** classified under the chlorophyl-less **fungi (mycetes),** under the general grouping of **schizomycetes** ( ).

While **most diseases** are probably due to, or associated with, bacteria, **very few bacteria,** relatively speaking, **cause disease.** The great majority of them are of undoubted value to other living organisms.

There are **three general shapes** after which bacteria are named. The **bacillus** is **rod-shaped** (b, f, k, l, Fig. 88), the **coccus** (c, d, e, f, h, Fig. 88), (sometimes micrococcus), is **berry-shaped** or spherical, and the **spirillum** is **spiral-shaped** or merely curved, something like a comma (A, Fig. 88). Bacteria may be so small that only many thousands together form a spot sufficiently large to be seen under a high power microscope, or they may be of relatively large size. That is, they vary from less than **1 micron** (the measurement used in microscopy, meaning 1-1000 of a millimeter, or 1-25000 part of an inch) to 30 or 40 microns. It has been estimated (Migula) that there are 1272 distinct species of bacteria.

Not only do bacteria vary according to shape, but as to their method of growth under varying conditions of temperature and surrounding substance.

Bacteria may possess cilia or flagella and move quite rapidly. They reproduce by simple binary fission. The spirillum and bacillus divide at right angles, usually lengthening slightly before division. Cocci may divide in different planes, and various names have been assigned to them on this account. If they divide into two parts but remain attached, they are called **diplococci** ( ). If they continue dividing in one plane but remain attached so as to form chains, they are called **streptococci** ( ). If they divide in two planes,

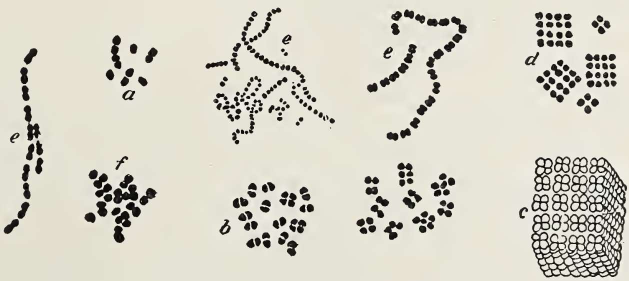


Fig. 89. Various Groupings of Spherical Forms of Bacteria.

a, Tendency to lancet-shape; *b,* coffee-bean shape; *c,* in packets (sarcina); *d,* in tetrads; *e,* in chains (streptococcus); *f,* in irregular masses (staphylococcus). Magnified 1000 diameters. (After Flügge.)

they are called **staphylococci** ( ); and if in three, **sarcina** ( ). (Fig. 89.)

Sometimes the protoplasm of bacteria breaks up into a number of bodies within the cell. These bodies are called **endospores** ( ). The value of this breaking up is supposed to be similar to that of encysted amoeba; namely, to permit the organisms to await some more favorable feeding period and environment. During this spore state bacteria are very **resistant.**

The **sterilization** of various substances in the laboratory takes sporulation into consideration, so that when a substance is to be sterilized, it is placed in a temperature of 50 or 60 degrees C. for **several days in succession, rather than at a higher temperature at one time.** This permits the spores to germinate. As spores are hard to kill while in the spore-state, but readily succumb when placed in a 50 or 60 degrees C. temperature after germination, it will be seen that this intermittent sterilization is the best method so far known.

Fischer has divided bacteria into three groups, according to the nature of their metabolism: "(1) Bacteria which are like the green plants in requiring neither organic carbon nor organic nitrogen. These are the so-called prototrophic bacteria, which possess the remarkable property of being able to build up both carbohydrates and protein out of carbon dioxide and inorganic salts. (2) Bacteria which need organic carbon and nitrogenous compounds. These are called the metatrophic bacteria. (3) The paratrophic bacteria which live as true parasites and can exist only within the living tissue. This group cannot manufacture its own food and is like other animals in this respect. The metabolism of bacteria may then show all of the phases already described for green plant cells and for animal cells as well as certain additional phases. The food is absorbed directly through the cell wall and is as varied as is their habitat. There seems to be no form of organic substance living or dead that may not serve as a source of food supply for bacteria, so that the enumeration of their foods becomes practically impossible. A special phase of the metabolism of bacteria is illustrated in their relation to nitrogen compounds. Nitrogen in an uncombined state cannot be used as food energy by most plants. It is obvious that the amount of ammonia, nitrites, and nitrates would soon become exhausted unless there were some way of supplying more of the nitrogen compounds. Many of the soil bacteria are prototrophic in habit and carry on the important work of combining the free nitrogen into a form that can be used by other organisms. The several nitrogen combinations are effected through the agency of several kinds of bacteria. There are also bacteria which live in the roots of certain plants, like clover, beans, and peas, which are able to utilize the nitrogen of the air. All of the higher forms of plants and all of the animals are dependent upon microscopic bacteria for their nitrogen. It would be very strange if the character of metabolism which is so fundamental in living things should be essentially different in bacteria; it probably is not, and so the usual steps in assimilation and dissemilation may be assumed to take place in bacteria. During this process enzymes are utilized and toxins produced."

Bacteria increase with marvelous rapidity by becoming larger in size, followed by a division of each organism into two. If each of these divide every half hour, a single bacterium will have become something like 17,000,000 individuals in twenty-four hours. It can be seen quite readily that such a tremendous increase in so short a time means that vast quantities of food must be at the bacteria's disposal, or the organisms themselves must die. If they are then in the body of an animal, the effects of the poisons produced by their dead bodies may be an important factor in injuring the host.

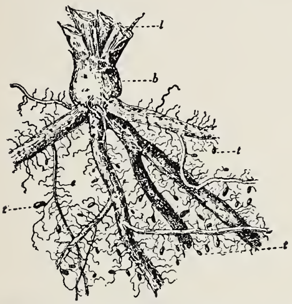


Fig. 90. Tubercles (Galls) on the Roots of Red Clover.

l, section of ascending branches; *b*, enlarged base of stem; *t*, root-tubercles containing bacteria.

However, comparatively few types of bacteria are pathogenic. Most of them have some useful function. They are the chief agency in decomposition and decay by which they help to restore organic materials into the general circulation of nature's economy.

Bacteria spoil food and rot substances which then become soil fertilizers; they sour milk and ripen cheese; they break down tissues in disease, and aid in digestion. They do much that makes life in the higher organisms possible, while at the same time doing many things which cut that life short.

While it was only after microscopes were invented that bacteriology could become a science, still it has always been known that acid solutions and salt solutions keep food from spoiling and that heavy sugar solutions do the same. Thus it was possible to pickle and preserve foods and to make jellies.

Bacteria require heat and moisture for their growth, so that fruit and meats can be dried. By preventing one of the important factors for bacterial life from being available, such meat can be preserved for great periods.

Drugs and chemicals which prevent the growth of bacteria are known as **antiseptics.** Thus, the ancients poured wine on wounds as an antiseptic. We use alcohol to-day instead of wine.

In agriculture there are certain soil-bacteria which produce tiny **galls** ( ), commonly known as **tubercles** (Fig. 90), on the roots of clover and other leguminous ( ) plants. These serve a very important purpose in that they derive nitrogen directly from the air and supply it to the clover. This makes it possible for clover to grow in soil very poor in nitrogen, while the over-possible for clover to grow in soil very poor in nitrogen, while the overproduction of nitrogen leaves the soil richer than it was before.

The galls themselves are filled with rather large x- and y-shaped bacteria, easily seen under the microscope. These bacteria die, and the nitrogen which they contain is added to the surrounding soil, sometimes directly, and sometimes through the intermediate plant to which it is attached.

CHAPTER XIV

IMMUNITY

WHETHER the study of Biology be taken up by those who intend to practice medicine, or for general cultural purposes, the fact remains that all of us, at some time in our lives, require the services of a medical man. Likewise, all of us, who make any pretense whatever at being college men and women, feel, and rightfully so, that unless we can intelligently follow at least ordinary scientific articles in the various magazines and journals published for educated men and women, there has been some radical defect in our instruction.

Practically all modern medicine is based upon the theory of immunity, and neither the medical man, the medical student, nor the educated man at large, can intelligently discuss or intelligently understand anything that may be told him regarding himself or the method of treatment suggested when disease comes to him, unless the theory of immunity is understood.

The subject of immunity is rather difficult. It is, in fact, probably one of the most difficult which confronts the first and second year student of Biology; but his ability to grasp and understand the theory is, in a way, a test of his ability at understanding and applying the knowledge he has gained in Biology.

All coelomates have their bodies arranged as one tube lying within another, and, if one could draw out any coelomate body lengthwise, the outer part would appear as a tube with very thick walls, while the gastro-intestinal-tract would form an opening through the entire body. In fact, the whole body would appear quite similar to an ordinary thickened gas pipe (Fig. 164).

One can readily understand that the opening in the gas pipe is really subject to the same atmospheric and environmental conditions that the outside of the pipe may be. So, too, the intestinal tract, with all its diverticula, is really outside of the body in so far as the atmospheric surroundings are concerned. In fact, the interior portion of the gastro-intesinal-tract is just as much outside the body (although not quite as much exposed) as is the skin on the outer surface.

Now, the surface on the inner side of the gastro-intestinal-tract, just as the skin, forms a layer which can, under certain conditions, be penetrated by either physical, chemical, or living substances. We know that we can scratch or cut ourselves. This results in a physical injury. We know that poisons are chemicals which can injure tissues whenever such poisons get into the system, and we also know that living organisms, such as bacteria (unicellular organisms from the plant world) and protozoa (unicellular organisms from the animal world), can take up a sort of parasitic life within other living forms. Whether a given substance injures chemically, or whether a living organism is to find its way into another and injure it, depends upon whether or not the foreign substance or organism can penetrate through the outer skin-surface of the body or through the surface of the gastro-intestinal-tract. It is only when such foreign objects are able to get **within the body proper** (that is, within the space between body surface and intestinal surface) that injury results.

Probably most of such injurious substances are taken in through the mouth and later find their way through the more or less delicate lining of the gastro-intestinal-tract. It is of value to note that the severity of a burn, in the area affected, depends upon the length of time the particular area remains in contact with either fire or acid. This means that a deep or severe burn in a localized area may cause death, while a less severe burn spread over a greater area may not.

Now, if a liquid, which can neutralize or wash away the given substance, could be thrown upon the acid at the time it is spilled, such acid would be washed away immediately, and little, if any, harm would be done. So, too, in the gastro-intestinal-tract, an injurious substance which may find its way therein, may be neutralized or washed away if a sufficient quantity of neutralizing fluid is secreted or passed through the intestinal tract.

Therefore, two things must be kept in mind when discussing a subject of this kind: the **strength or power of the injuring agent,** and **the length of time the injuring agent remains in contact with a susceptible surface.** In fact, one may add a third factor, for there is a possibility of a foreign substance being taken into the system which may so affect the regenerative abilities of the host, as not only to prevent healing of a wound, but which will actually continue to irritate and injure more than the original injuring agent.

Once the injuring agent has entered the body, the question arises as to the method by which it injures the host. It must be remembered that living organisms, whether they be bacteria or protozoa, are in turn subject to the same laws which govern the life of the host itself. Some of the larger parasites, such as tapeworms, really remain within the intestinal tract and use the food of the host before the host himself derives the benefit of what he has eaten. There are also parasitic protozoans, such as the malarial parasite, which, once it has entered the blood stream, actually eats out the center of the blood cells. Then there are those which use some part of either the blood or other tissues of the body for food and in this way injure the host; or again, there are those which use but a very small quantity of the host's food and are consequently not particularly injurious to the host on that account; but the various excreta ejected by these parasites may prove injurious either as a mechanical obstruction of some kind or as a chemical poisoning. And still again, various poisonous substances may be formed by the parasites themselves, which will injure the immediately surrounding tissues of the host only in the location of the parasites; or, the poisons may be soluble in the blood stream and in this way pass throughout the entire body, injuring many regions. And there is still another way by which injury is brought about by parasitical invaders. There are certain bacteria and protozoa which require considerable oxygen for their life processes. The red blood corpuscles have become red by coming in contact with the air in the lungs and absorbing oxygen which they then distribute throughout the body. If the parasite, however, takes this oxygen from the red blood cells, only carbon dioxide and, under certain conditions, carbon monoxide remains. Carbon monoxide is a constituent of "coal gas," which often asphyxiates men working in coal mines. It, therefore, follows that one actually may be "gassed" and die of this "gassing," if the body contains parasites which remove the much-needed oxygen from the red blood corpuscles. In such instances where oxygen is withdrawn, death results almost immediately.

Then there may be all manner of **mixed infections.** Just as it requires fire in order to cause powder to explode, so there are certain chemical substances, as well as living organisms, which by themselves do little harm or injury; but, when a second or third substance mixes with them, may prove quite injurious. Conversely, a single substance may be quite injurious, such as either an acid or an alkali; but, when the two are mixed, they neutralize each other, and no active injury is brought about.

Everyone knows that no two people are exactly alike in their ability to resist disease, and that one person may tolerate a much greater injury than another without succumbing to it. Most of us have probably read of the ancient king who, being afraid that an enemy might poison him, took small doses of various poisons daily so that in due time he could take great quantities without its having any injurious effect upon him. That is, his **toleration** for this specific poison grew, and his body was able to resist the usual injury caused by such poison. That is, his system became insensible to specific poisons which were thus unable to affect him injuriously because an immunity to these poisons had been set up.

Resistance, **tolerance**, and **immunity** may be classified in various ways, such as **racial, familial**, and **individual.** As an example of race immunity we have those groups of individuals living in the tropics who do not succumb to the various tropical fevers that affect a stranger almost immediately. The classic example, however, is that of the Jews, who having fought tuberculosis for thousands of years, are now more immune than any other known race of mankind. The Negroes and Indians, on the contrary, never having had tuberculosis until the white man brought it to them, succumb quickly.

If certain families seem to be more or less immune, we call this a familial immunity, and if only an individual is intensely resistant to a given disease or injury, we speak of it as individual immunity.

Immunity is also divided into (1) **natural immunity** (under which racial immunity can be classified), and (2) **artificial immunity.** The second of these divisions is again subdivided into **active** and **passive immunity.**

Bacteria either **contain** poisonous substances (endotoxines), as does the typhoid fever bacillus, or they **produce** poisonous substances (merely called toxins or ectotoxines) as does the diphtheria bacillus, tetanus bacillus, etc.

Now, if these toxic substances are distributed within the body, the body tries to protect itself by manufacturing **antitoxins,** which are opposing substances for the purpose of neutralizing the poisons and thus preventing them from injuring the system. If the toxic poisons are not too severe, the antitoxin prevents a disease from forming.

As an example we may cite typhoid fever. Here the antitoxin is not only manufactured, but actually remains in the body of the patient for some years after the disease has passed away. The great quantity of antitoxin present can, during these years, thus prevent another attack of the disease if the typhoid bacillus again gets into the body. Such an individual is, therefore, during the time the antitoxin is present in his body, **immune** to new attacks of typhoid fever. He is immune because his body produced immunizing bodies which protect him. His body is active in producing these immunizing bodies, and such immunity is therefore called an **active immunity.**

An animal which, in a specific disease, also builds up such antibodies or immunizing bodies, may have these antibodies removed from its blood. The liquid part of the blood, which contains the antibodies, is called an **antibacteriological** or **antitoxic serum.** Such sera are then injected into human beings. As the person, into whom they are injected, then has protective substances which he does not otherwise have, he (without having his own body manufacture the antibodies) becomes immune for a certain length of time to the specific disease for which the **antibodies** were manufactured in the animal's body. Such an immunity is. therefore, called a **passive immunity.**

It is upon principles evolved from these facts that the various vaccines have been brought forth against cholera, typhoid fever, smallpox, etc., as preventive measures, as well as the therapeutic sera injected **after** the disease is present, as in meningitis, diphtheria, tetanus, etc.

We know that various chemical substances have definite affinities for each other, and, to explain the mechanism of immunity, it is assumed that every cell in the body has some particular chemical attachment or affinity. Let us say that a certain molecule connected with each cell has an affinity for various substances which pass through the body. This molecule is called a **receptor.** We know that normally, as blood passes the different cells of the body, the cells have a **selective action;**

that is, they practically reach out and drink in what they need. One of the experiments performed on **Paramoecia** demonstrates what is meant by this chemical selective action. It is there shown that certain chemical substances, such as a sugar solution, may cause the animal to go in an opposite direction, but, if it has once gone into the solution, it will not again leave. This selective action, which all cells probably possess to some degree, may work on a similar basis; that is, normally, the molecule (the receptor) draws to itself the particular food that it needs as the blood passes. But, just as **Paramoecia** may actually enter the sugar solution or even an injurious solution, so the molecule or receptor may also sometimes take or select from the passing blood various poisonous or toxic substances and unite them with itself. This, of course, injures the cell to which the receptor is attached.

We know from ordinary observation that, whenever we injure ourselves sufficiently, a **scar** forms. Then, too, it will be noticed that the scar is almost always slightly elevated. This means that **more scar tissue has actually formed than there was skin before.** From microscopic studies we find that, whenever those particular cells known as **fibroblasts** (which form a goodly portion of the connective tissue element of the body) are injured, they grow much more rapidly and profusely than they did before such injury took place; in other words, if the fibroblasts are injured, more connective tissue will grow in the region of injury than grew originally. Once an injury takes place and regeneration or regrowth begins, there is usually an excess of such regeneration or growth.

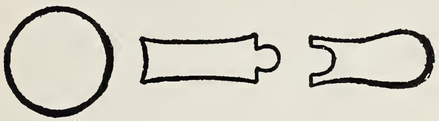


Fig. 91. Diagram Illustrating the Factors Concerned in Immunity.

cl., the cell to be dissolved; *c.*, the complement or solvent by which it is dissolved; *a.*, the amboceptor or intermediate body by which the two can be brought together.

With this in mind it is easy to understand that, when a molecule or receptor has anchored to itself a poison (Fig. 91) which injures the cell to which the receptor is attached, the cell may grow several receptors where it had only one before. Such excessive production of receptors causes a portion of the receptors to be thrown off from the cell. These separated receptors then find their way into the blood-stream. The receptors in the blood-stream are able to anchor poisons to themselves just as when attached to cells. This means that there are great quantities of these receptors taking up the poison which would otherwise injure the various cells with which the poisons might come in contact. The receptors thus prevent injury to cells which normally would be open to attack.

Certain conditions, however, must be fulfilled before the receptors can unite to themselves the poisonous substance, and the condition necessary in this instance is that a certain ferment-like substance, called a **complement** (or **alexin**), be present. These are protectors against infection.

Complements can be demonstrated to exist in the laboratory. When blood serum is placed in a test tube, the receptors do not unite with the toxin if a very small amount of heat is applied to the serum proper. Heat kills or paralyzes whatever it is that makes the union possible. If, however, we add but a very small amount of unheated serum, the union takes place almost immediately. Whatever it is that has been destroyed by the heating and permits or causes the receptor to unite with the poisonous substance, is called the **complement.**

It is quite possible that certain cells of the body, or even all the cells of some animals, may have no receptors at all for certain poisons, and, therefore, such cells and animals would have a natural immunity toward those poisons. It is because the thrown-off receptor needs the complement before it can anchor the poison that it has been called **amboceptor.**

The foreign body or substance is called the **antigen,** while the amboceptor produced by the action of injurious antigens is known as the **antibody.**

It is of great importance to know that the molecule which is the amboceptor is decidedly **specific.** That is, an amboceptor will react only to one specific foreign substance, so that antibodies formed in diphtheria, for example, will not be the same as those formed in tetanus, nor will they be able to assist in anchoring poisons produced in tetanus.

Quite naturally, the rate and ability of metabolism in a cell will determine how rapidly receptors are formed, and consequently will determine how rapidly immunity can be brought about. This means, in turn, that, if the poisons can act more rapidly than the cells, the cells as well as the possessor of those cells will succumb.

The growth, development and action of **phagocytes** (white blood cells which devour foreign substances) are also subject to this same rate and ability of metabolism. Some phagocytes may devour a foreign body before the latter has time to bring about an injury.

Some phagocytes may not have within themselves a chemical substance which can dissolve the invader, and so the invader may continue to live even though engulfed by a phagocyte, or, the invader may even kill the phagocyte.

Then it must be remembered that in all parasitic organisms the same conditions largely apply which apply in the host, so that, just as the host may strengthen his resistance, so the parasite may strengthen its virulence to overcome the increasing resistance of the host. For example, about the bodies of the anthrax bacillus and the pneumococcus, capsules form which make them more resistant to any injurious substances of the host. And these capsules only form in the body of a host where some kind of immunity is possible. In cultures in the laboratory, where no immunity is brought into play, capsules do not form on the groups mentioned.

The encapsulated forms are not subject to phagocytic action, and some even continue to produce more and more powerful poisons to injure the unlucky phagocyte which may devour it.

It is assumed that inflammations and fevers probably cause an increased production of phagocytes and chemical neutralizations to protect the body in injury and disease.

The amboceptors anchor soluble poisons only when the complement is present.

Similarly, phagocytes will not engulf bacteria unless the bacteria have first been prepared for such engulfing by substances in the normal blood serum similar to the complement called **opsonins.** If an animal has been immunized already by repeated introductions of bacteria, still more resistant bodies called **bacteriotropins** appear. These bacteriotropins (which are only a sort of outstanding opsonin in immune sera) act as opsonins and prepare the bacteria for the phagocytes. Opsonins, bacteriotropins, and in fact all substances which prepare foreign substances for the phagocytes, are called **cytotropins.**

When foreign bodies of any kind dissolve body substances, they are said to be cytolytic (kytos-cell+lysis-dissolving) if they dissolve the cytoplasm; haemolytic, if they dissolve the red substance (haema=blood) in the blood cell; hepatolytic (hepar=liver) if they dissolve liver cells, etc., etc. Such lysins are usually antibodies.

If a reaction can be produced, which will cause bacteria or cells to clump together, such clumping is called **agglutination,** while the substances in immune sera which cause agglutination are called **agglutinins.** This is commonly called the Widal reaction. Agglutination is so specific that the serum of an individual suffering from typhoid fever, or even the serum of one who has had the disease, will cause the clumping of typhoid bacilli when a few drops of it are placed in a culture of the bacilli.

If any foreign protein substance is injected into any of the higher animals, new substances similar to antibodies are formed. These are also specific in acting on the same protein substances by causing a cloudy precipitate, and sometimes by changing the protein by breaking it up into simpler substances, some of which are poisonous. This fact makes it possible to tell whether blood stains are those of a human being or not. For example, the clear serum of a rabbit can be treated with human blood serum and, if even a portion of the dissolved human blood stain is then added, a cloudy precipitate forms, although this precipitate will not form when blood from a lower animal is added. Similarly, if the rabbit's blood be first treated with the blood of a lower animal, human blood will not cause the precipitate.

A strange phenomenon has also come forth in recent years, known as an **anaphylactic** shock. This is probably connected in some way with the precipitation reaction. It means that an animal already immunized to a protein may die when additional protein of the same kind is injected. This condition in an animal is known as **anaphylaxis** ( ). In other words, we may say anaphylaxis is an oversensitiveness of the organism toward bacterial toxins and foreign sera. The reason for anaphylaxis is not yet satisfactorily explained.

The principle of anaphylaxis is used to diagnose certain diseases. The tuberculin reaction is nothing more nor less than the injection of the proteins of the tubercle bacillus into the skin, which (because the dose is very small) does not overwhelm the entire nervous system, but produces only a fall in temperature and a slight fever, if the disease is present.

An **antitoxin** is, as already stated, the soluble substance produced which neutralizes quantitatively fresh injections of the same poison. The commercial diphtheric antitoxin is merely the serum of a horse which has had repeated doses of diphtheria toxin injected until it has been brought into a state of active antitoxic immunity. Like all immunizing agents, antitoxins are all specific for some single toxin.

In this connection it is interesting to note that sheep, while they are very susceptible to the toxin formed by the tubercle bacilli, are not susceptible to the injection of the dead bacilli themselves. Guinea pigs are quite susceptible to the bacilli but not to the toxin. The proteins of our own body injected into ourselves are poisonous.

The various ways in which immunity is produced by injection of foreign substances, may be summarized as follows:

(1) The virulent parasites are administered in small doses so as to give the individual the disease in a mild form (active immunity).

(2) Weakened parasites may be injected in larger doses and produce the same result.

(3) Dead bacteria may be given in place of living, so as to produce a feebler but similar result.

(4) The poisons may be isolated from the parasites, and gradually increasing doses injected, thus increasing the normal neutralizing ability of an individual.

(5) Serum from an animal, immunized by one of the above processes, may be placed directly into another individual and thus permit him to become immune without going through any form of the disease himself (passive immunity).

CHAPTER XV

THE PLANT-WORLD

SIMPLE PLANTS

EVERYONE is already familiar with some of the higher groups of plants known as "flowering plants," but everyone is not familiar with the fact that flowering plants are few in number, indeed, when compared with the thousands of different kinds of minute plants that cannot even be seen with the naked eye, and which do not bear flowers.

Prominent among these latter are such single celled plants as Pleurococcus, the yeasts, and bacteria already studied. But there are others also, which, though commonly seen, must remain unknown unless observed under the microscope.

To be able to discuss the plant-world intelligently one must know certain terms commonly used, just as it was necessary to know the various names of the many parts of the frog before the animal-world could be intelligently discussed.

The following outline and drawing (Fig. 92) will give such a knowledge of terms:

- Plant Body
  - Root (with or without branches)
  - Shoot
    - Stem (with or without branches)
    - Blade
      - Apex
      - Margin
      - Base of the Blade
      - Veins
    - Leaves
      - Petiole (the leaf-stalk)
      - Leaf-base
      - Stipules. (Small leaf-like structures at the base of the petiole.)

There are as many and varying classifications of plants as there are of animals, but, **four great groupings** hold their own because these groupings are simple and easily understood.

They are as follows:

Thallophytes ( ). Plants possessing a simple plant body. These are made up of:

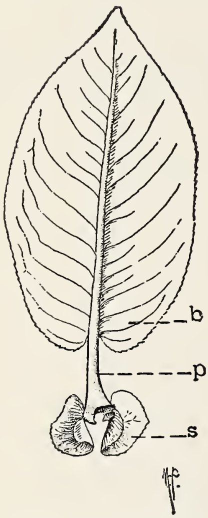
Algae (Chlorophyl-bearing thallophytes).

Fungi (Thallophytes without chlorophyl).

Bryophytes or **Moss Plants** ( ).

Pteridophytes and their allies ( ). The ferns and their allies.

Spermatophytes or seed plants ( ).



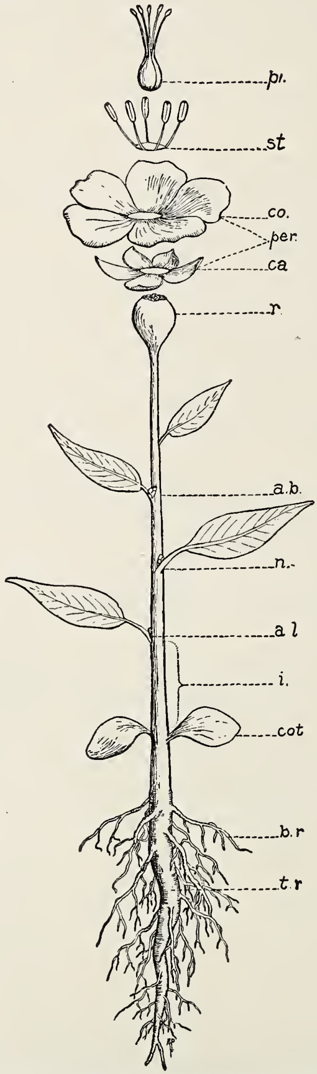


Fig. 92. Leaf, Root, Shoot and Flower.

A. Leaf of a willow *(Salix sp.)* *b.*, blade; *p.*, petiole; *s.*, stipules.

B. Diagram to show the essential parts of a "flowering" plant. *t.r.*, tap-root; *b.r.*, branch root; *cot.*, seed-leaf (cotyledon); *i.*, internode; *a.l.*, leaf-axil; *n.*, node; *a.b.*, axillary bud; *r.*, receptacle of floral organs; *ca.*, calyx; *per.*, perianth; *co.*, corolla; *st.*, stamens (androecium); *pi.*, pistil (gynoecium).

(From C. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Sons & Co., Publishers.)

THALLOPHYTES

Thallophytes. These plants have a mere **plant body** without a true stem, roots, or leaves, though there may be parts that resemble stems, roots and leaves. They may be very fragile, as are some of the thread-like green **Spirogyra** (Fig. 93), (also called **pond-scum** and **frog-spit**), commonly found in fresh-water creeks and ponds, or tough **sea-weeds,** like the **brown kelp** many feet in length. The cells usually grow end to end.

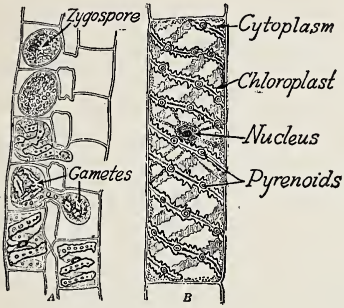


Fig. 93.

The band-like chloroplasts extend in a spiral from one end of the cell to the other. In them are imbedded nodule-like bodies *(pyrenoids),* and near the center of the cell the nucleus is swung by radiating strands of cytoplasm. (After Strasburger.)

As was seen when living organisms were discussed, there are no hard-and-fast rules by which one may classify anything. There are some Thallophytes which really have stem-like and leaf-like structures, but the classification originally based on structures, must now be thought of more from a **functional** or **life-cycle** point of view. All thallophytes are alike in having a more or less simple life-cycle, so this must serve us as a basis.

The various algae (Fig. 94) are named after some distinctive characteristic; thus those which are **green** are called **Chlorophyceae** ( ); those which are **red, Rhodophyceae** ( ); those which are slimy, **Myxophyceae** ( ), etc.

Spirogyra ( ) is in turn a representative of the **Chlorophyceae.** The cells are elongated and attached end to end. There are spirally arranged bands (chromatophores or chloroplasts) which contain chlorophyl. The number of these bands and the method of coiling depend upon the species to which each belongs. The cytoplasm is rather thin and lies next to the cell-wall, while fine threads of it extend to the nucleus. The special centers in the chloroplasts, where starch is stored, are called **pyrenoids** ( ). Nearly 98 per cent of the cell is water, yet the two per cent remaining can perform every one of the four vital processes. The bubbles often seen are filled with oxygen which is a waste product of photosynthesis.

Reproduction takes place in two ways, either by the individual cell dividing at right angles to the length of the cell, or after two individuals have conjugated. The latter is seen when two plants lying close together send out projections (Fig. 95) which unite, forming bridges through which the cytoplasm of one plant mixes with another. In fact, these two cells may unite so thoroughly that they become one, becoming smaller as a thickened wall is secreted about it. When this latter event takes place, the organism is said to be in a **spore state**, and because the spore has been formed by the fusion of two cells, it is often called a **zygospore** ( ). Conjugation is thus a preparatory process to permit a mixing of the parent chromatin before actual reproduction takes place.

It has already been explained that a sexual germ-cell is known as a **gamete.** The zygospore is, therefore, now one cell, the product of the fusion of two **gametes.** There is here, then, the beginning of sex-life in the plant-world. This is why the two conjugating and fusing parent cells are known as gametes.[1]

The spore cannot escape from the parent cell, however, until such parent-cell decays.

Artificial Fertilization. — Something like a hundred years

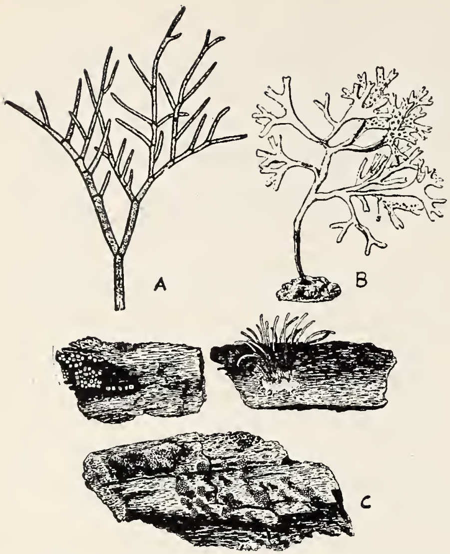


Fig. 94. Chlorophycae, Rhodophycae, and Myxophycae.

A. *Cladophora,* a branching green alga, a very small part of the plant being shown. The branches arise at the upper ends of cells, and the cells are cœnocytic.
B. A red alga *(Gigartina),* showing branching habit, and "fruit bodies."
C. Three common slime moulds (Myxomycetes) on decaying wood: To the left above, groups of the sessile sporangia of *Trichia;* to the right above, a group of the stalked sporangia of *Stemonitis,* with remnant of old plasmodium at base; below, groups of sporangia of *Hemiarcyria,* with a plasmodium mass at upper left hand. (A, after Caldwell; B, after Schenck; C, after Goldberger.)

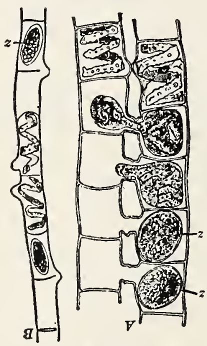


Fig. 95.

The Union of the Gametes in *Spirogyra.*
A, two filaments of *Spirogyra quinina,* side by side, showing stages in the union of the cells (gametes) to form the zygospores; *B,* another species *(S. longata),* in which the cell unions occur between adjacent gametes in the same filament. (After Schenck.)

Fig. 96. A Common Foliose Lichen *(Parmelia)* Growing Upon a Board, and Showing Apothecia. (After Goldberger.)

[1]This is the first sign of two sexes we shall see in the laboratory, although the very first sexual differentiation in plants probably lies in the *Volvacales* (Fig. 97).

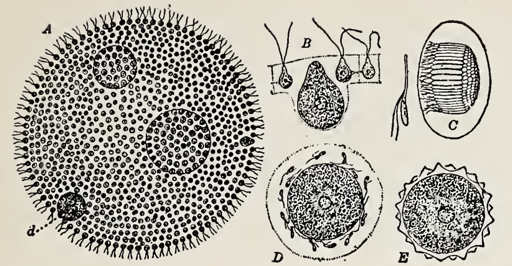


Fig. 97.
Volvox Globator, a Colonial Form of the *Volvocaceæ.* (See Fig. 49, where this same form is considered an animal.)

A, mature colony, with four daughter colonies developing in its interior; *B,* section of the edge of the colony, showing three vegetative cells and a developing egg; *C,* a packet of sperms within the parent cell and a single sperm very much magnified at the side; *D,* an egg surrounded by a swarm of sperms; *E,* an oöspore with heavy protective wall. (From Bergen & Davis' "Principles of Botany," by permission of Ginn & Co., Publishers.)

ago Spallanzani fertilized the eggs of various animals artificially, while more recently several workers have succeeded in causing eggs to begin to grow by chemical means. The experiment was first successfully made with the eggs of sea-urchins and other marine animals by a zoölogist, Loeb. In 1913, Overton successfully accomplished the same thing with the eggs of **Fucus**. The eggs were dipped in a mixture of 50 cc. of sea-water plus 3 cc. of a very weak solution of acetic, butyric, or other fatty acid, for about a minute, or a minute and a half to two minutes, and then transferred to normal sea-water. The formation of the fertilization-membrane was caused in this way quite as in natural fertilization by the sperm. It was also found that, after the formation of the membrane, if the eggs are placed for 30 minutes in **hypertonic** sea-water (50 cc. of normal sea-water plus 8 to 10 cc. of a weak solution of sodium chloride or potassium chloride), and then back into normal sea-water, the eggs will begin to divide and continue to develop into young plants. The chromosome number in the cells of plants formed by artificial fertilization, although a question of very great interest, is still unsolved.

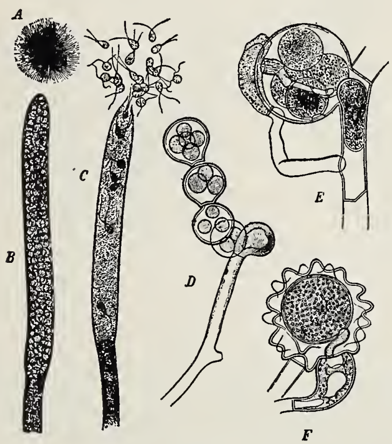


Fig. 99. *Phycomycetes.*

These are the alga-like fungi without septa in the mycelium, except in the sporing branches, where they occur to cut off the spore-bearing cells. The septa also occur in old filaments. The mycelium is therefore continuous.

Common water mold *(Saprolegnia)*: *A,* a fly from which mycelial filaments of the parasite are growing; *B,* tip of branch organized as a sporangium; *C,* sporangium discharging biciliate zoöspores; *F,* oögonium with antheridium in contact, the tube having penetrated to the egg; *D* and *E,* oögonia with several eggs. *(A-C* after Thuret; *D-F* after De Barry.)

Fig. 98. Growth Habit of the Bread Mold *(Rhizopus Nigricans.)*
Sketch showing two groups of erect hyphæ bearing sporangia, with root-like clusters of filaments at their bases.

It must be remembered that the egg was already there. Artificial fertilization merely hastened a normal action. This does not throw any light on the origin of life as it is popularly supposed to do.

VAUCHERIA

This is the common "**green felt**" (Fig. 86), usually found on soil, although it is often also found in water. The thread-like filaments are coarser and longer than spirogyra, and they also branch. Vaucheria are **tube algae.**

There is an interesting difference here from the spirogyra in that there are **no transverse cell-walls** throughout the entire filament, but many nuclei are scattered about. Such a form is called a **coenocyte** (   ) or **syncytium** (I. E., Fig. 86).

Fig. 100. *Ascomycetes* (Sac-like Fungi).

The figure shows the characteristic grouping of asci. The layer in which the asci appear is called a hymenium. In these the mycelium has dividing septae and the spores are contained in asci. (After Chamberlain.)

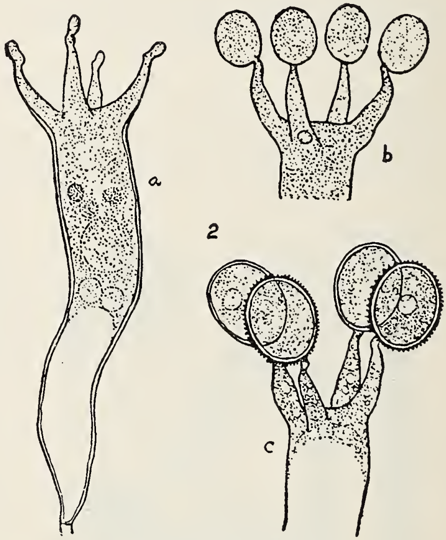


Fig. 101. *Basidiomycetes.*

Typical basidium with sterigmata (distal short stalks), showing spores in different stages of development. (After De Barry.)

In basidiomycetes the spores develop on little club-shaped hyphae. Smuts, rusts and mushrooms belong in this group.

Reproduction takes place **both sexually and asexually** (Fig. 86). In the latter case the old end of the filament dies, setting free the branches which become separate plants, or a **cross wall** forms in one of the branches. A thickening occurs beyond this cross wall, and this thickening is known as a **zoöspore.** The zoöspore breaks away from the parent plant, swimming about for a time, and then becomes a new plant.

It is made up of many cells but forms only one plant.

Sexual reproduction occurs when one or more large oval protrusions form on branches which have grown out apparently for this purpose. At the very end of this branch is the **terminal** cell in which many small cells are formed. These small cells escape into the water. Each one possesses long cilia by means of which it swims about. A single one of these ciliated forms enters the oval mass. The little ciliated form is known as the **male gamete,** and the large oval protrusion as the **female gamete.** The **organ which produces a gamete** is called a **gonad**[1] ( ). The oval body is consequently known as an **oögonium** ( ) or **egg-gonad.** Two gametes, uniting as have the two just mentioned, form a single cell known as an **oöspore.** This oöspore, after a short period of rest, forms a new plant. It will be noted that in vaucheria the gametes are of **unequal size.** In spirogyra they were of **equal size.** In fact, **whenever gametes are formed,** it is **the smaller** and **more active** one, regardless of whether there are any other distinguishing features or characteristics, which is called the **male gamete** or **sperm,** while the larger and more passive one is known as the **female gamete** or egg.

The union of sperm and egg is called the process of **fertilization.**

The **male gonad** is called the **antheridium** ( ), and the **female gonad** is known as an **oögonium.**

Some algae live with various fungi. These **symbiotic** ( ) plants are the **lichens** ( ) (Fig. 96).

THE FUNGI

The **Algae-like,** or **tube fungi,** make up the **Phycomycetes,** while the higher fungi, such as mushrooms, toad-stools, puff-balls, rusts, and smuts, are known as **Carpomycetes.**

The fungi, no matter how differently they may appear or in what out-of-the-ordinary place they may grow, are alike in two great characteristics: 1. **They possess no chlorophyl,** and 2. **They reproduce by spores.**

They live either upon decaying matter, in which case they are called **saprophytes,** or at the expense of another organism when they are called **parasites.**

Bread Mold is easily obtainable, but that from fruits or from dead flies serves just as well for study (Fig. 98). There is a tangled mass of **thread-like structure** which is the working body of the plant. This tangled mass is known as **mycelium** ( ), while the individual threads are known as **hyphae** ( ). If the hyphae send out threads in turn, these are called **rhizoids** ( ), and these little root-hairs penetrate the substance on which the mold forms and through which it absorbs what is needed. It is supposed

[1]Botanists do not look with favor on the term "gonad" in plants, but it has seemed advisable to use this term here, for, in zoology the student must use it constantly.

that **enzymes** are produced **in the hyphae** which can make the bread or fruit utilizable to the plant.

Reproduction takes place by a number of **upright stalks,** called **sporangiophores** ( ), growing from the mycelium. There is formed a **spore-case,** or **sporangium,** at the very tip of the stalk. In this the spores are formed and, when the spore-case bursts, the dust-like particles, which are really spores, are scattered about by **air** currents.

There may be **sexual reproduction** in the molds quite similar to that in Spirogyra. Two hyphae unite by their free ends and a wall forms, thus producing **two end cells** which eventually become a **single spore with a very dark heavy wall.** Here again, **the gametes being similar,** the resulting body is a **zygospore.** The sexual process does not occur very often.

It is to be remembered that molds are plants. But growing as they do in the dark, they have no chlorophyl and do not make their own food. They feed on food already prepared, not on ordinary plant or animal food as does man, for example, but on decaying matter or on food that has already been digested by the host, either before or after assimilation.

The so-called water-mold is both parasitic and saprophytic as it can thrive either on dead or living fish. Molds are said to be a **degenerate form** of **green plants** which have **acquired a habit** of making some other organism do their work for them, rather than build their own food by photosynthesis as plants usually do.

PATHOGENIC FUNGI

There are many difficulties in the way of working out a satisfactory classification of the pathogenic fungi because botanists and pathologists do not always use the same name or employ the same method. Botanists classify **fungi** or **mycetes** ( ) as follows:

1. **Phycomycetes:** algae-like fungi. (Fig. 99.)

2. **Ascomycetes:** sac-fungi (asci); asexual spores formed in sacs. (Fig. 100.)

3. **Basidiomycetes:** spores, borne on little club-shaped hyphae, or basidia. (Fig. 101.) (Includes smuts, rusts, and mushrooms.)

Pathologists take the following points into consideration and arrange their classification under the title of pathogenic protophytes:

Most infectious diseases due to **vegetable parasites** are caused by **bacteria,** but a few owe their origin to micro-organisms of a higher type, namely, to the **yeasts** and **molds.** Two of the infectious processes caused by yeasts, although comparatively rare, deserve brief consideration. Both the organisms and the **lesions** they produce, microscopically and in gross, resemble each other more or less closely. For this reason they were for a long time confused with each other, but the differential characteristics are now fairly generally recognized.

The relation of the **yeasts** or **blastomycetes** to the bacteria and the molds is shown in the following diagram:

Pathogenic Protophytes.

(These are all Chlorophyl-less plants.)

Schizomycetes ( ) | **Hyphomycetes** ( )
(bacteria) | **(molds)**

Blastomycetes ( )
Saccharomycetes ( )
or
Ascomycetes ( )
(yeasts.)

Oidia ( )
(transition form)
Oidium.

Blastomyces.

A living organism may be injured either **mechanically** or **chemically.**

Mechanical or physical injury may be the result of **violence**, **pressure, heat** (burning), **cold** (freezing), **light rays**, and **electricity.**

Chemical injury results from poisons (toxins), whether by auto-intoxication, or toxins produced by animal or vegetable parasites.

It is readily understood that a parasite may cause either mechanical or chemical injury to its host: the former by propagating so rapidly that it causes a physical obstruction, as is the case with the tubercular bacillus; and the latter by a definite poison that the foreign organism produces. The poison, or the mere mechanical effect, may in turn cause some out-of-the-ordinary conditions, as for example when it furnishes a stimulus to overgrowth on some part of the host, as **galls** on trees (a growth caused by the stimulus of **aphids**), or tumors in human beings. These latter are merely overgrown healthy cells.

These overgrown healthy cells may press against neighboring blood vessels, obstructing the blood-flow and thus cause the death of the tissue which fails to receive its required amount of blood.

It may be stated in this connection that there are some hosts which are not affected at all, or but little, by the poisons parasites produce, although the parasite itself does many such hosts a great deal of damage.

The subject of toxins is among those of which no great knowledge has yet been obtained. Toxins are of great interest and importance as can readily be judged from what has been said.

Probably, if **toxins** and **enzymes** are thought of here in relation to each other, it will lead to a clearer understanding of each. Both can be studied only by the **effects they produce**, the one injurious, the other beneficial.

One may also think of several other possibilities on the part of the invading organism. For example, it may live entirely at the expense of its host, in which case it is a **parasite**; it may live on decayed matter and do little if any injury, and thus be a **saprocyte**; or it may actively engage in killing and devouring parasitic invaders and thus be of great value to its host. In the last instance it is known as a **phagocyte**.

True yeasts grow **by budding** (Fig. 87); they **rarely form mycelia; under** unfavorable conditions of growth they may form **endospores.**

Oidia grow by budding and as **mycelia with spore formation.** (Fig. 102.)

Hyphomycetes (Fig. 98) grow as mycelia **with spore formation of asexual or sexual origin.**

All authorities seem agreed that there is no sharp line of demarcation between the blastomycetes and the hyphomycetes, and most of them place the oidia as a transition form.

Fig. 102.

Oidium, showing spores being cut off from the tip of the branch. Such spores are called *coindiospores.*

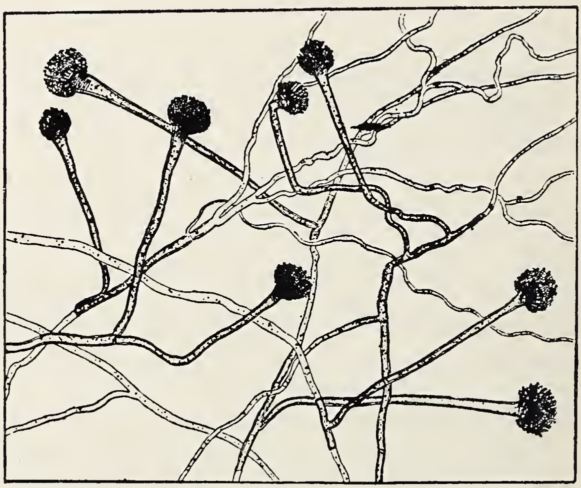


Fig. 103. *Aspergillus Fumigatus.* (After Brumpt.)

Blastomycosis (also called saccharomycosis), is the term applied to the lesions produced by a blastomyces. A variety of organisms have been cultivated from the lesions, and different names have been assigned to them. It is not known if these are distinct entities.

There is an infection in the skin, usually remaining localized there, but it may invade the circulation and cause lesions in other parts of the body.

The blastomyces occur in human tissues only, as small round bodies with granular protoplasm, and with thick hyaline capsules. They multiply by budding only in human tissues, but in cultures they may either develop mycelia or grow by budding or do both. They may be numerous in the lesions which they produce, or few and hard to find.

They produce a fairly strong toxin.

Aspergillus fumigatus (Fig. 103) is an example of the **pathogenic** ascomycetes. It is a fungus widely distributed, usually as a harmless parasite, having been found in the auditory canal, nose, and throat.

In birds and in cattle, and more rarely in dogs, aspergillus may cause lesions of the lungs, resembling tuberculosis, and of late years a good many cases have been reported in man, particularly pigeon keepers and hair sorters. In the majority of these cases the infection is secondary to some long-standing affection of the lungs, though it also causes a primary lesion resembling broncho-pneumonia, usually quite serious. The patient coughs up a grayish-brown mass the size of a bean made up entirely of mycelium and spores.

Oidiomycosis (granuloma coccidioides) is the term applied to the lesions produced by an oidium. In the past this organism has been called immities, coccidioides, etc., but it is not yet definitely classified by botanists. Infection with this organism is rare and is confined almost exclusively to California. The disease is practically fatal.

The oidium occurs in human lesions in the form of spherical bodies which may reach a size of thirty microns. They consist of an irregularly staining mass of protoplasm enclosed within a double contoured capsule which is occasionally covered with prickles, or even long spines. The organisms multiply in tissues only by endosporulation, never budding. The spores may number as high as a hundred or more. They are liberated by the bursting of the capsule. The number of parasites in the lesions varies. The parasites may be many or few and hard to find. In cultures the oidium grows as long septate branching hyphae. In time, spores develop in the ends of the hyphae and are infectious. To inoculated animals, the hyphae, themselves, are not infectious.

The lesions produced by oidium often bear a close resemblance to those caused by the tubercle bacillus, and have probably been mistaken for them more than once on histologic examination. If the organisms are few in number, a cheesy region may be formed, and if numerous, even abscesses and ulcers.

Blood and lymph streams seem to carry the organism so that it is widely distributed. It is as likely to be found primarily within, as upon the skin of the body.

Like the tubercle bacillus, oidium involves the same organs; lungs, lymph-nodes, adrenal glands, meninges, seminal vesicles, etc.

The skin lcsions are chronic and consist of nodules, abscesses, and ulcerations.

DISEASES CAUSED BY FUNGI OF MORE OR LESS UNCERTAIN POSITION

Actinomycosis or lumpy jaw.

SPOROTRICHOSES

The **Sporotrichoses.**

(a) **Subcutaneous.** Small solid nodules, becoming abscesses, ulcerating the skin.

(b) **Cutaneous.** Principally in arms, hands and legs, though it may occur on other parts of the body. Ulcers form in groups of two or three.

(c) **Localized,** hard and eroded on surface.

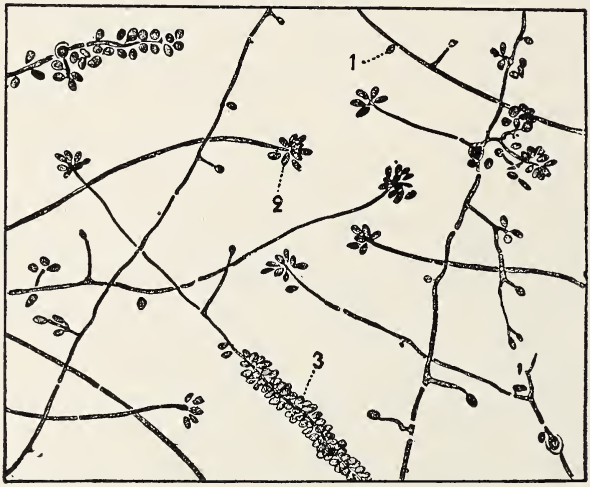


Fig. 104. *Sporotrichum Beurmanni.* (After Brumpt.)

1, Single lateral conidiospore; 2, terminal conidiospores; 3, collection of laterial conidiospores.

The parasite (Fig. 104) is introduced by accidental inoculation, and possibly through the eating of grains and fruit. It acts like bacteria, producing toxins, toward which toxins there are active reactions of the body-fluids. It is a short rod 3 to 5 microns long and 2 to 3 microns in breadth. In cultures it grows in filaments of about 2 microns in diameter and forms characteristic ovoid spores.

The points of differentiation between the various forms of this organism are due largely to the variation in its modes of sporulation.

Fig. 105. *Actinomyces Bovis.* (After Rivas.)

Parasite producing actinomycosis (lumpy jaw). Actinomyces bovis, also called *nocardia actinomyces, nocardia bovis, streptothrix actinomyces, streptothrix israeli, oospora bovis, cladothrix actinomycoses,* and *bacterium actinocladothrix.*

Nocardiosis. The parasites (Fig. 105) resemble bacteria, on one hand, and on the other the hyphomycetes or molds, by forming branching, thread-like filaments, and by producing fine conidia. They represent a **transition** between bacteria and the lower fungi. The results of infection are similar to tuberculosis or multiple abscesses. Three cases have appeared as abscesses of the brain.

Mycetoma or Madura disease. This disease is found principally in India, though it does occur in other parts of the world. There are great swellings of the foot, generally on the sole, nodular growths and multiple abscesses. Black, brownish, or yellow granules are formed, one micron in diameter.

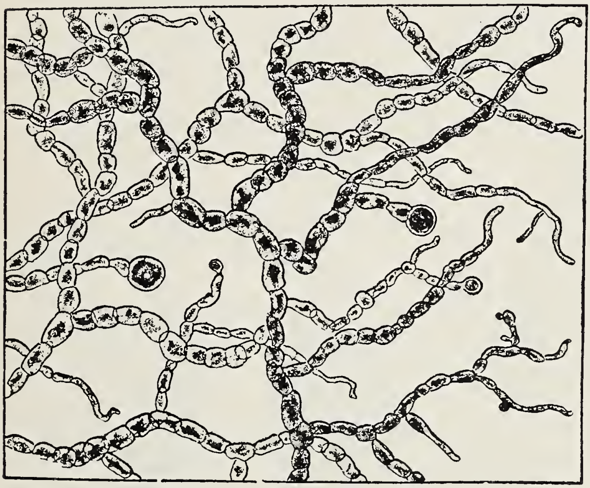


Fig. 106. *Madurella Mycetoma.* (After Brumpt.)

A variety of Streptothrix (Fig. 106) has been found in the pale colored granules, closely resembling actinomyces. Most observers seem to hold that this **Streptothrix madurae and Actinomyces** are distinct species. From the variety having black granules, a hypomycete has been grown, which is closely allied to Aspergillus.

In medicine, all diseases caused by any non-bacterial fungi are sometimes called **Mycosis.**

It is worthy of note that medical men, being mostly interested in disease, take **similar appearing** lesions as their basis for classifying organisms, while biologists classify organisms according to structure and development, often with little reference to what disease such organisms may cause.

CHAPTER XVI

THE PLANT WORLD CONTINUED

THE THREE HIGHER GROUPINGS

BRYOPHYTES

BRYOPHYTES are usually said to possess **archegonia** (   ), or **primitive egg gonads,** composed of **many cells,** as contradistinguished from the **thallophytes** which, **when they possess gonads at all,** are practically always **composed of single cells.**

Bryophytes are moss plants and liverworts, and their life cycle consists of two stages, the sexual and the sexless. When these stages follow each other, an "**alternation of generations**" occurs. The **sexual plant,** or **gametophyte,** forms **eggs** and **sperm** which unite, while the **asexual plant** or **sporophyte** is the plant which grows from the fertilized egg of the sexual plant. This nonsexual plant forms asexual spores which, in turn, grow into gametophytes.

Bryophytes may be quite simple, resembling the thallophytes, or they may form a leafy stem as in the mosses.

There are some 12,000 different species of mosses or **Musci,** as they are technically known. These are divided into three distinct orders:

1. **Sphagnales** (   ). The peat mosses. (Fig. 107.)

Fig. 107.
The Peat Moss,
Sphagnum.

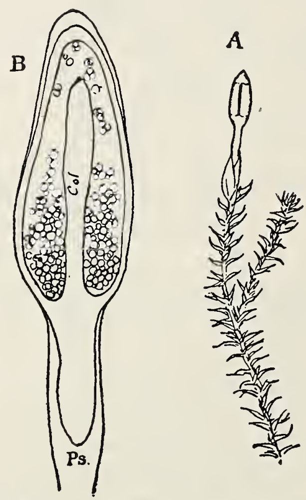


Fig. 108. *Andreæa Petrophila.*
A, plant with mature sporophyte. B, longitudinal section of sporophyte. Ps, pseudopodium; col., columella. (From D. H. Campbell's "A University Text-Book of Botany," by permission of The Macmillan Co., Publishers.)

2. **Andreaeales** ( ). The black mosses. (Fig. 108.)

3. **Bryales** ( ). The true mosses. (Fig. 109.)

Fig. 109. A Common Moss.

(Catharinea Undulata). Showing the branching leafy moss plants (gametophytes) attached to the rootlike mass of protonemal filaments and bearing sporophytes. (After Sachs.)

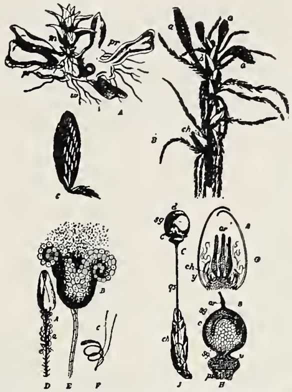


Fig. 110. *Sphagnum Acutifolium, Ehrb.* *A.*, prothallus *(pr.)* with a young leafy branch just developing from it; *B.*, portion of a leafy plant; *a.*, male cones; *ch.*, female branches; *C.*, male branch or cone, enlarged with a portion of the vegetative branch adhering to its base; *D.*, the same, with a portion of the leaves removed so as to disclose the antheridia; *E.*, antheridium discharging spores; *F.*, a single sperm; *G.*, longitudinal section of a female branch, showing the archegonia *(ar.)*; *H.*, longitudinal section through a sporongonium, with dome of sporogeneous tissue; *ar.*, old neck of the archegonium; *J.*, *Sphagnum squarrosum* Pers.; *d.*, operculum; *c.*, remains of calyptra; *qs.*, mature pseudopodium; *ch.*, perichætium. (After Schimper.)

The **Sphagnales** are the **most primitive,** and the **Bryales** the most **highly developed.**

Sphagnum (Fig. 107) is a peat moss, growing, as its name implies, in swamps and along the margin of lakes. The peat bogs of northern regions are made up of thick clumps of this plant. Peat mosses are usually light green in color, bordering on white, and sometimes have a slight tinge of red and yellow.

The plant has certain branches which bear reproductive cells, and other branches which are sterile. (Fig. 110.)

The **gamete plant** (the one bearing the gametes or reproductive cells) has an upright stem with a mass of pith in the center. The outermost portion is called the **cortex.** The cell walls in the cortex are thicker than those in the center, and often contain pigment. The cortex varies from two to four cells in thickness. The leaves are only one cell in thickness, and never have a **midrib** or other veins. In other words, there are **no fibrovascular bundles** in the stem. The lack of fibrovascular bundles is one of the great characteristics which distinguish this whole group of plants from the next higher grouping—the **Ferns.**

As the leaves mature, a goodly portion of the cells increase in size, because the entire protoplasm is added to the walls of the cell so that these become very thick. This leaves the cell filled with nothing but air and water. In fact, this **hygroscopic** ( ) **ability** of the cells of Spagnum is the reason florists use the sponge-like **Sphagnum** in packing flowers for shipment.

In those branches which are set aside for reproductive purposes, each sex uses individual branches for the **antheridia** (male branches) and the **archegonia** (female branches) (Fig. 111). In some species,

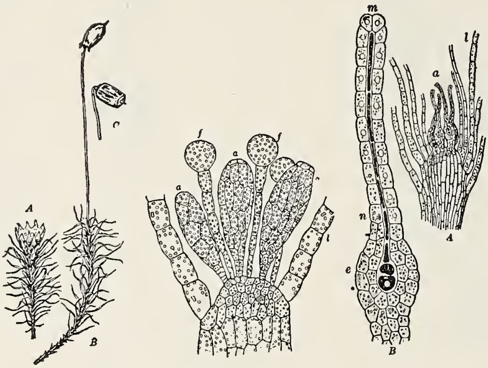


Fig. 111. Antheridia and Archegonia.

A Common Moss *(Polytrichum commune)*. *A*, male plant, showing cup-like tip containing the antheridia. *B.*, female plant with the sporophyte; *cal.*, cap, or calyptra, over the developing spore case; *C.*, a mature spore case with the calyptra removed.

Section Through the Tip of the Male Plant of a Moss *(Funaria)*. *a.*, antheridium; *f.*, sterile filament, or paraphysis; *l.*, leaf.

Section Through the Tip of a Female Plant of a Moss *(Funaria)*. *A.*, group of archegonia *a.*; *l.*, leaf. *B*, an archegonium in detail, showing enlarged basal portion *e.* with the egg, and the neck *n.* above with its row of canal cells; *m.*, mouth. (After Sachs.)

(From Bergen & Davis' "Principles of Botany," by permission of Ginn & Co., Publishers.)

entire plants are of one sex or the other. In these, therefore, antheridia and archegonia are never found on the same plant. Such plants are said to be **dioecious** (from two households), while those plants, on which both male and female reproductive branches appear, are said to be **monoecious** (from one household).

The branches bearing antheridia are called **antheridophores.** An antheridium is found in the **axil** ( ) of each leaf of the head and consists of a stalk composed of not more than four rows of cells. When the antherium is mature, it contains many sperm.[1] (Fig. 112.) The sperm are coiled, and bear two long thread-like cilia at their anterior

[1]Botanists use "sperms" for the plural of "sperm," while zoologists do not. We have, therefor, kept the term "sperm" throughout as meaning both singular and plural.

end. There is a small appendage, called a vesicle, which contains starch granules. As the antheridia ripen, the sperm-sac is forced open, and this sperm discharged. It is important that this **sperm-sac** be not confused with the **spore-capsule** to be mentioned later.

The branches bearing archegonia are called **archegoniophores** and are usually found toward the upper portion of the plant, while the archegonia themselves are at the tip of the archegoniophores (Fig. 113). Each archegonia has a **neck, neck-canal,** a **venter** which contains the egg, and a **basal** or **pedicel.** The archegonia of ferns will also be found to be quite like this, except that the pedicel is missing. Usually, several archegonia are found on a single branch. A number of enlarged leaves surround the archegonia. They constitute a **perichaetium** (   ).

Fig. 112.
The Antheridium of a Common Moss (*Funaria*).
a., Antheridium; *b.*, escaping sperm; *c.*, a single sperm in its parent cell. (After Sachs.)

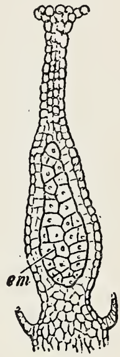


Fig. 113.
Archegonium of *Sphagnum*, showing a young embryo sporophyte *(em.)* developing in the venter. (After Schimper.)

Both archegonial and antheridial branches begin growing close together, but the main branch, from which both develop, continues growing between them and separating them further and further.

Fertilization probably occurs in winter as young embryos are found in abundance in the spring. A film of water is needed for the purpose of

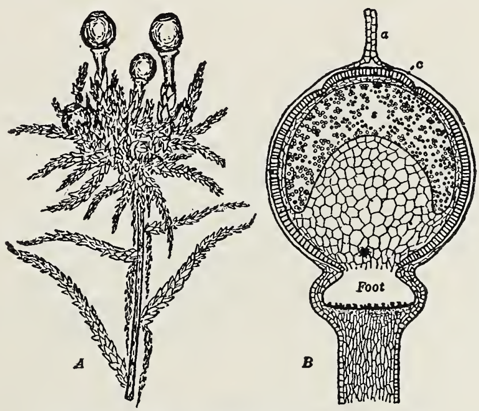


Fig. 114. The Sporophyte of the Peat Moss (*Sphagnum*).
A., group of the sporophytes on stalks, which are really growths from the gametophyte. *B.*, longitudinal section through a sporophyte, showing the large foot imbedded in the top of the stalk; *a.*, the remains of the parent archegonium, with the neck still present; *s.*, a spore chamber; *c.*, cover. (From Bergen & Davis' "Principles of Botany," by permission of Ginn & Co., Publishers.)

fertilization because sperm must swim to the neck-canal and pass through this into the venter. Here it enters the **egg** where the nuclei of sperm and egg unite. The fertilized egg now divides by mitosis very rapidly, and the upper cells form a large **globular spore-case** with a thick central column within known as the **columella.** This is surrounded by a dome of spores, around which the wall of the sporangium is formed. The spore-case later pushes against the wall of the archegonium by enlarging. The wall is then ruptured, the top portion remaining as the **calyptra** (   ) (Fig. 119), while the spore-case later opens by means of a lid. The lower cells produced by the dividing oösperm become a swollen **foot**, which is imbedded in the tissues below. It remains connected with the spore-case by a short stalk.

The structure, which thus develops from the fertilized egg-cell, is called the **sporophyte** (Fig. 114) stage of sphagnum. In fact, all such simple plants which develop spores are called **sporophytes.**

Simultaneously with the maturing of the sporophyte, the apex of the female branch elongates into a leafless stalk about half an inch or more in length, known as the **pseudopodium.** It is supposed that the reason that the pseudopodium and sporophyte grow thus simultane-

Fig. 115.

Antheridium of *Pteris (B.)*, showing wall cells *(a.)*, opening for escape of sperm mother cells *(e.)*, escaped mother cells *(c.)*, sperms free from mother cells *(b.)*, showing spiral and multiciliate character. (After Caldwell.)

Fig. 116. *Sphagnum sp.*

A., B., young protonemata; *C.*, older protonema with leafy bud, *k.*; *r.*, marginal rhizoids. (After Campbell.)

ously, is probably due to the fact that cells in the foot secrete a substance which stimulates the cells to divide and enlarge, resulting finally in the formation of the pseudopodium. The advantage the plant gains is that the spore-case is raised to a higher plane, and it can thus throw its spores much farther than would otherwise be the case.

As **Sphagnum** possesses no chlorophyl, it does not manufacture its own food and must, therefore, live on the absorption of food-matter from the gamete plant through the foot.

The spores themselves develop in the following manner (Fig. 115). In the spore-case the inner cells differentiate into two kinds, one making up the larger portion of the tissues, and the other, larger and richer in protoplasm, forming a dome of **sporogenous** or **spore-forming tissue** near the upper wall. It is from this latter type of cell that the **spore-mother-cells** are developed.

These spore-mother cells are divided twice, thus producing four spores each, and it is these spores which eventually **germinate** and produce the **gametophytes.** In ferns, we shall see that a quite similar process of spore formation takes place.

During the time the spores are **maturing,** a circular groove, called an **annulus,** forms near the **apex** of the spore-case. The cells in this region have thinner walls than the surrounding cells. These cells later become dry, and the thinnest part becomes torn to form a lid or **operculum** (   ) at the summit of the spore-case. As the operculum falls away, the sperm are dispersed.

Fig. 117.
Sphagnum Cuspidatum, showing innovation, or short, branches. (After Schimper.)

If they find suitable soil, a short green **protonema** (Fig. 116) germinates. The tip of the protonema broadens to form the prothallus which is one cell in thickness. Tiny **rhizoids** (   ) form on the under side and from the margin, while other threads containing chlorophyl then develop. Often a thallus forms at the tip of each of these threads. From this thallus a leafy branch grows upward, and the sphagnum plant described is again a full-fledged adult organism. The plant, from the time it germinates from the

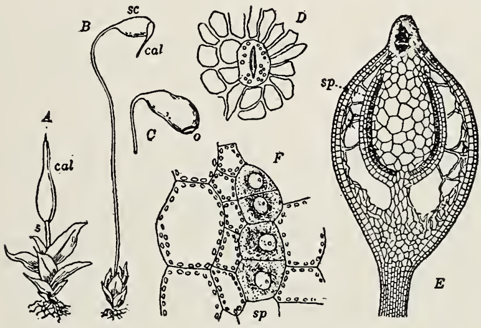


Fig. 118. I.
The Sporophyte of a Common Moss *(Funaria).*
A., young sporophyte *s.* attached to the leafy moss plant and covered by the calyptra *cal.* *B.,* sporophyte with mature spore case *sc.* and calyptra *cal.* at the tip. *C.,* spore case with calyptra removed; *o.,* the cover (operculum. *D.,* a stoma from the surface of the spore case. *E.,* section of young spore case, showing the cylindrical central region of spore-producing tissue *sp.* F., the spore-producing tissue in detail. (From Bergen & Davis "Principles of Botany," by permission of Ginn & Co., Publishers.)

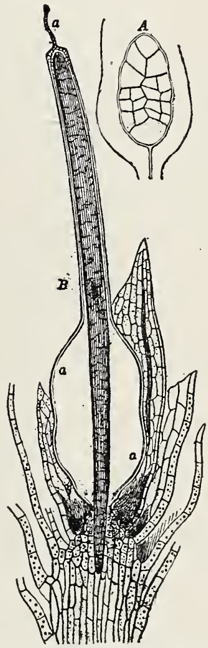


Fig. 118. II Developing Sporophytes of a Common Moss *(Funaria).*
A., very young stage, showing the early cell divisions of the egg; *B.,* older sporophyte just before the archegonium *a.* is torn away from the gametophyte and carried upward as the calyptra. The base of the sporophyte has now grown down into the tip of the leafy moss plant (gametophyte) and is firmly anchored to it. (After Sachs.)

spore until the thallus develops, is the **gametophyte.** This is to be distinguished from the adult plant which, as we have seen, is called the **sporophyte.**

There is an **asexual** multiplication of sphagnum also. This is brought about by a sterile branch which develops more powerfully than the surrounding ones. Then, each year, as the old stem dies off below, the young branch becomes a new plant. Sometimes little plantlets, known as **innovation branches** (Fig. 117), strike root and become independent plants. These innovation branches spring from close to the tip of the sterile branches.

The life-cycle of Sphagnum may be summarized as follows:

OUTLINE OF LIFE HISTORY OF SPHAGNUM

Sphagnum-plant **(gametophyte)**

Antheridial branch — Archegonial branch

Antheridia — Archegonia

Sperm (male gamete) — Egg (female gamete)

Fertilization

Oösperm (zygote)

Embryo

Mature Sporophyte

Sporangium

Spore-mother-cell

Spore Spore Spore Spore } **Reduction**

Protonema

Thallus

Sphagnum-plant **(gametophyte)**

The so-called **true mosses** (Fig. 109) have life-histories quite like that of sphagnum, although there are differences. In true mosses the protonema produces leafy branches (the true moss-plants), but it does not produce a thallus. The leafy branches arise directly from the filamentous protonema. True mosses are both monoecious and dioecious. There is no pseudopodium (Fig. 118), but the stalk of the sporophyte which is very short in sphagnum, here elongates to form a **seta**, often more than an inch in length.

Fig. 119.

A Moss *(Tetraphis sp.)*, showing gemmæ; *G.*, a gemma enlarged. (From C. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Son & Co., Publishers.)

The true mosses have little breathing pores called **stomata** at the base of the capsule. Sphagnum has the stomata, but they do not function. Chlorophyl-bearing cells surround these stomata, so that in the true-mosses there is some food actually manufactured by photosynthesis.

The sporophyte of the true mosses seems to occupy an intermediate position between sphagnum and the next higher group of plants, the Ferns. There is an increase in sterile tissue as we approach the ferns, and a decrease in fertile tissue in the sporophytes.

From experiments so far performed it seems that every cell of the moss-plant can, like the tissue-animal Hydra, which we shall soon study, develop a protonema—that is, each cell is **a potential spore**. Each protonema produces buds which become mature plants.

There are certain species of mosses in which the leafy-shoot, and in others, the **protonemata,** give rise to a special type of small bodies called **gemmae** (Fig. 119) (   ), which become separated from the parent plant and give rise to new plants.

A comparison of Sphagnum and a fern (to be studied next) is of value here.

The commonly known "fern-plant" is a **sporophyte** while the Sphagnum-plant is a gametophyte.

The fern sporophyte is dependent on the gametophyte for nutrition, at first, then the sporophyte becomes entirely independent, while the simple gametophyte perishes.

The Sphagnum sporophyte is the simpler plant and it is this sporophyte which must depend upon the gametophyte for nutrition throughout its entire life.

Reproduction is quite alike in Fern and Sphagnum. Each produces haploid gametes of two sexes, which then unite in fertilization, the zygote being diploid. It is the zygote which produces the spore-bearing phase. The spores, which are in turn haploid due to a reduction having taken place, then give rise to the haploid gametophytes, so that we may sum up the life-cycle in both Fern and Sphagnum by saying: Gametophyte alternates with sporophyte, fertilization with reduction, gametes with spores, haploid cells with diploid.

It will be seen from what has been said, that this whole group of plants shows a **differentiation of cells into tissues,** while in the higher forms leaf-like structures appear. Then the **rhizoids** (specialized absorbing organs) are developed, and the plant tissues themselves contain chlorophyl. It is supposed that bryophytes have evolved from **aquatic forms** to **land forms,** and consequently, as parts of the plant have dried, various **structural adaptations** ( ) have been brought about.

PTERIDOPHYTES

These are the ferns (Fig. 120) and their allies in which the distinguishing feature is that these plants possess nearly everything that thallophytes and bryophytes possess, **plus a conducting or vascular system.**

These plants are supposed to have arisen "from a bryophyte ancestry where the sporophyte (sexless) generation, in some plants capable of doing chlorophyl work, developed a root system and vascular tissue, and taking the land habit, became independent of the gametophyte. This was one of the most important forward steps in the evolution of the higher plants, for it gave the sporophyte complete freedom to live and grow to its maximum size. This change marked a turning point in plant evolution, for, after the sporophyte became the most complex and conspicuous phase of the life-history, the gametophyte grew less prominent, until in the seed-plants the sexual generation became actually dependent or parasitic upon the asexual generation. This is a relation which is exactly the reverse of that which exists between the gametophyte and sporophyte in the liverwort and mosses."

"After the sporophyte became independent of the gametophyte, the next important advance was the development of the lateral spore-bearing and vegetative organs called **fronds** ( ). Then came the differentiation of the frond into vegetative **leaves,** given up entirely to chlorophyl work, and spore-leaves (sporophyls) devoted chiefly or wholly to spore production. With this also, came the massing of the sporophyls into **cones,** which was really the beginning of the structures called flowers in seed plants."

The pteridophytes have **underground stems (root-stocks or rhizomes)** so that only the leaves appear above ground. There is a **terminal bud** at the tip of the fern-stem. The **rhizome** bears **true roots,** and its **tissues are differentiated** into **epidermal, fundamental, mechanical,** and **conducting systems.** In the tropics there are tree ferns, many of which have been found among the fossil plants.

The **spore-cases** grow in groups, called **sori** ( ), on the **underside of the leaves** (Fig. 121). As the **annular ring** about each individual spore-case dries up, that side which is thinnest and has become dried most, splits open, throwing out the spores. There are usually 64 spores in each **sporangium.** These spores drop on to the moist earth and grow into a **minute plant,** by first absorbing moisture, and then, as the osmotic pressure becomes too great on the inner portion, breaks, and sends out a tiny tube (Fig. 122). This process is called **germination** ( ). Then a smaller tube appears close to the spore body growing from the tiny tube just mentioned, and this is the beginning of the root-like bodies, the rhizoids, which are

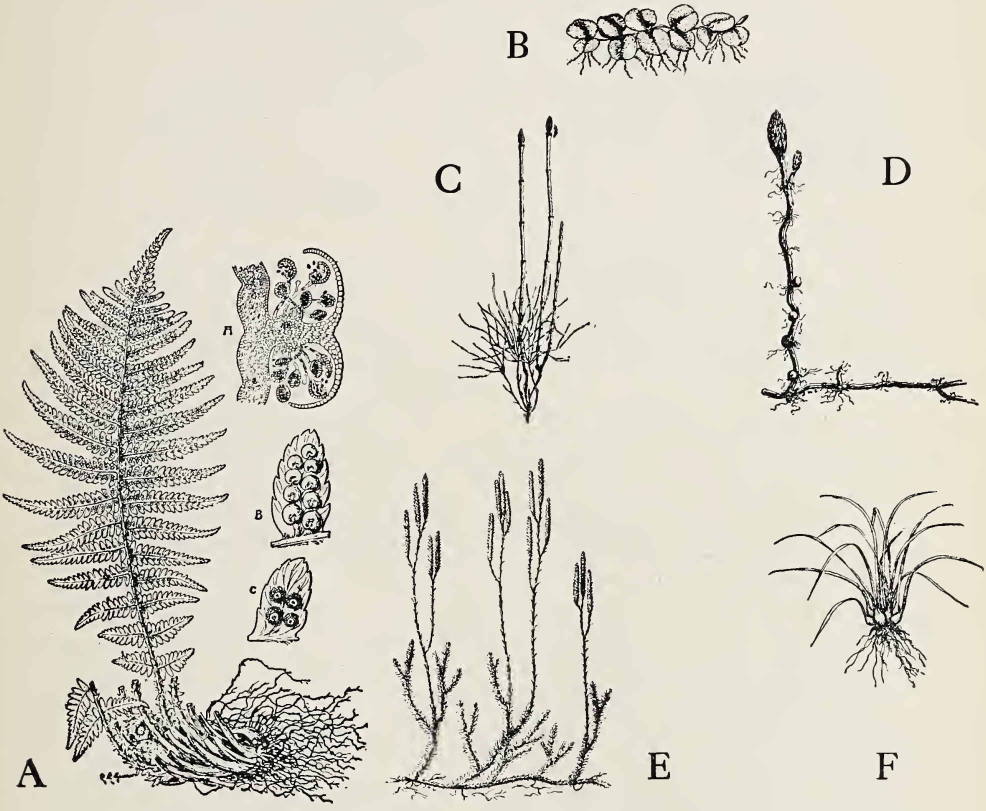


Fig. 120. The Ferns and Their Allies.

A. Fern plant (Aspidium), showing roots, rhizome, and frond: *A.*, section of fruit dot (sorus), showing spore cases, some of which are ejecting their spores; *B.*, portion of a leaflet, showing unripe fruit dots; *C.*, portion of a leaflet, showing ripe fruit dots. (After Strasburger.)

B. Order I. Salviniales (Floating Allies of ferns). *Salvinia natans.*

C. Order II. Equisetales. Branched Equisetum. *Equisetum Funstoni,* commonly called "Scouring Rushes," as distinguished from the "Horsetails" (also called Equisetales). The stems of Horsetails die each year and the fruiting cones have no terminal point.

D. Field Horsetail, showing buds and tubers.

E. Order III. Lycopodiales (Club-mosses). Common Club-moss, *Lycopodium clavatum.*

F. Order IV. Isoetales (Quillworts). Braun's Quillwort, *Isoetes echinospora Braunii.*

(A, after Strasburger; B to F, from W. C. Clute's "The Fern Allies," by permission of The Frederick A. Stokes Co.)

to hold the plant in place and absorb moisture and food material from the ground.

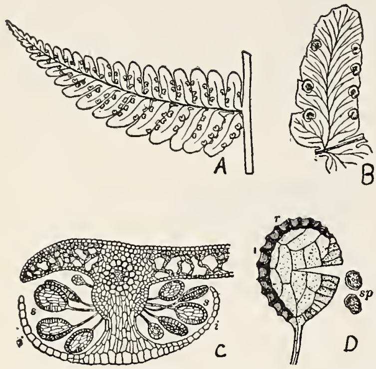


Fig. 121.
A., a leaflet of the frond viewed from below to show the position of the sori. *B.*, details of the sori and veining on a portion of a leaflet. *C.*, section of a sorus; *i.*, indusium; *s.*, sporangia. *D.*, a spore case or sporangium, showing the opening from which the spores *(sp.)* have been discharged; *r.*, ring. (From Bergen & Davis' "Principles of Botany," by permission of Ginn and Co., Publishers.)

This minute plant, which develops from the spore, is called the **prothallium** ( ). It is **often heart-shaped.** A portion just posterior to the notch, called the **cushion,** is **several cells thick,** and the outer part, called the **wings,** is **only one cell** in thickness.

Near the notch of the heart, close to the cushion, several flask-shaped bodies, called **archegonia,** are formed. Each archegonium contains an egg cell. **Among the rhizoids** are the **sperm gonads,** called **antheridia** ( ). Many tiny **motile cells** are found in the antheridia at maturity, but as these are discharged and find a small amount of moisture, they reach the egg and fertilize it.

It will thus be seen that here, too, as in the mosses, there is an alternation of generations, the ordinary fern being the asexual plant and the prothallus the sexual.

SPERMATOPHYTES

This group includes the plants which bear flowers like the rose and lily, as well as such flowerless groups as the pines which have their reproductive organs in cones or clusters, and are by no means so conspicuous as are those contained in a real flower.

Two older groupings of these higher plants are:

Phanerogams ( ). The flowering plants.

Cryptogams ( ). The non-flowering plants.

This grouping is one that came into existence before the sexual processes of plants had been studied to any extent, and so is not accurate, because the so-called **hidden** processes of the cryptogams are in reality more evident than those of the complicated phanerogams. As the **seed** is the **all-important part of a plant** from the reproductive point of view, the name **spermatophyte** has become popular. Seed plants, like ferns, are **sporophytes,** though there is a **gametophyte generation** in their life-history, but it is so reduced in structure that it is quite difficult to see. The seed must, therefore, be studied.

It can readily be understood that the seed, having a hard covering, which is wonderfully adapted for a protective purpose, lends itself well to long vitality, and makes it possible for the **embryo** to develop so far

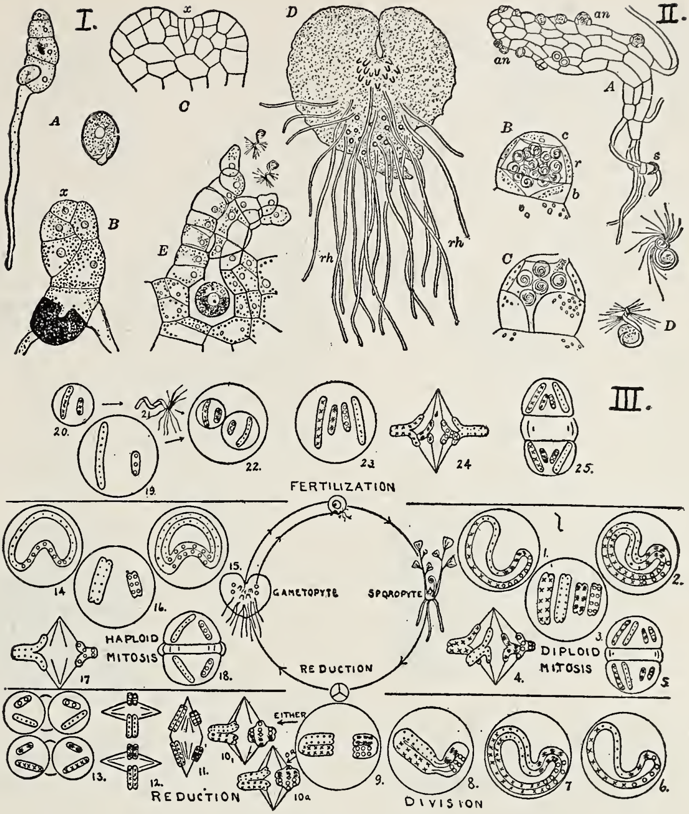


Fig. 122.

I. The Fern Prothallium and Archegonium.

A., stages in the germination of the spore. *B.*, young prothallium, showing first appearance of wedged-shaped, apical cell *x*. *C.*, tip of prothallium beginning to take on the heart-shaped form; *x.*, apical cell. *D.*, mature prothallium, showing group of archegonia on the cushion just back of the notch, and antheridia further back: *rh.*, rhizoids. *E.*, an open archegonium with egg ready for fertilization, and two sperms near the entrance of the neck. (*A.*, *B.*, *C.*, *E.*, after Campbell; *D.*, after Schenck.)

II. The Antheridium and Sperms of a Fern (*Onoclea*).

A., small prothallium with many antheridia *an.*: *s.*, old spore wall. *B.*, antheridium, showing cover cell *c.*, ring cell *r.*, and basal cell *b.*, inclosing the sperm mother cells. *C.*, antheridium opening. *D.*, *sperms*. (After Campbell.)

III. Diagram of a cytological life-cycle, based on a hypothetical fern with four chromosomes in the sporophyte. The nuclear phenomena are based on those of the thread-worm (*Ascaris*). Each chromosome is designated by a characteristic mark so that it may be traced throughout the diagram. (After R. F. Griggs.)

within its protective covering that it can take root and establish itself readily when the time is ripe. Then, too, the seed is a storage organ of condensed food for the embryo.

The **pollen grain** of seed plants produces a **male gametophyte** which bears either sperm or sperm nuclei.

In the **ovule** of seed plants there is a **megaspore** which produces an

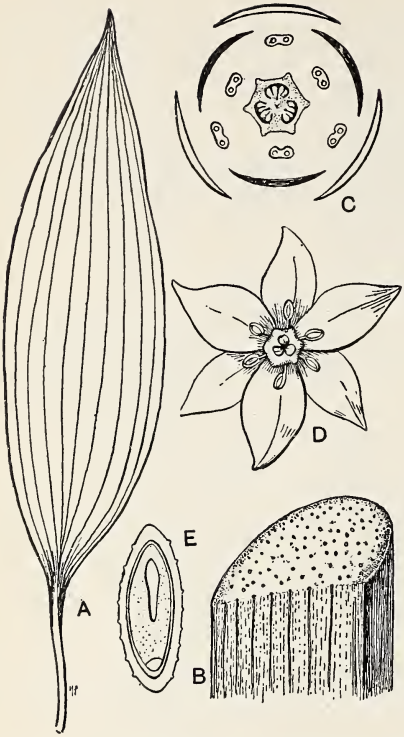


Fig. 123.—Morphology of typical monocotyledonous plant. *A*, leaf, parallel-veined; *B*, portion of stem, showing irregular distribution of vascular bundles; *C*, ground plan of flower (the parts in 3's); *D*, top view of flower; *E*, seed, showing monocotyledonous embryo. (From C. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Son & Co., Publishers.)

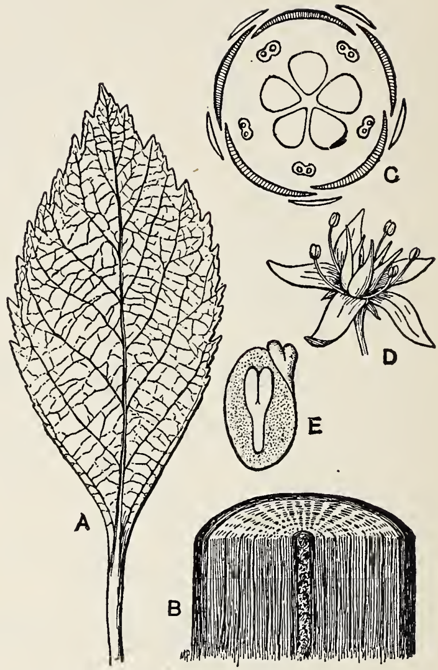


Fig. 124.—Morphology of a typical dicotyledonous plant. *A*, leaf, pinnately-netted veined; *B*, portion of stem, showing concentric layers of wood; *C*, ground-plan of flower (the parts in 5's); *D*, perspective of flower; *E*, longitudinal section of seed, showing dicotyledonous embryo. (From C. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Son & Co., Publishers.)

embryo sac in which the egg is formed. The pollen grain produces an outgrowth, or pollen tube, which penetrates the tissues surrounding the egg, and thus the sperm is carried to the egg, fertilizing it.

Seed plants are commonly divided into

Monocotyledons ( ). Example, lilies, corn, and grasses. (Fig. 123.)

Dicotyledons ( ). Example, beans and cotton. (Fig. 124.)

The drawings of various stem cross sections will illustrate the difference in the structure of the two types of seed plants. (Fig. 125.)

Angiosperms.—In this type of plant the ovules are produced in a **closed** ovary composed of one or more **carpels** ( ). The ovules become seeds, and the carpels and surrounding parts constitute a **fruit.** This fruit may consist of the **ripened ovary only,** or it **may include the calyx** ( ) **and receptacle also.**

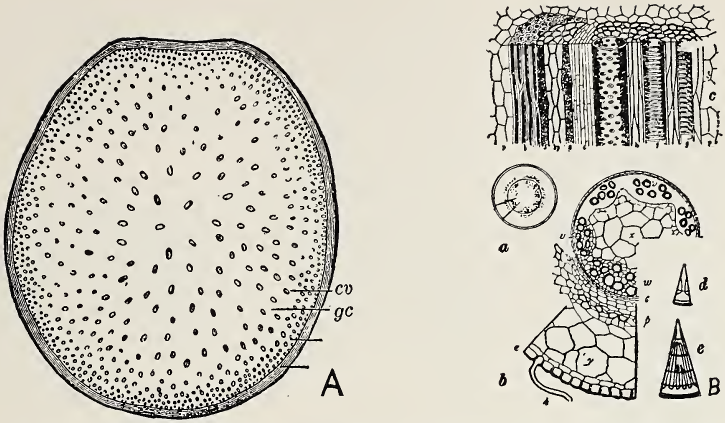


Fig. 125. *A*.—Diagrammatic Cross-section of Stem of Indian Corn (endogenous or monocotyledonous plant). *cv*, fibro-vascular bundles; *gc*, pithy material between bundles. *B*, Diagrams of stem sections (exogens or dicotyledonous plant). *a*, cross-section of chickweed stem, the inner circle representing the cambium ring, the two radial lines indicating the portion enlarged in *b*; *e*, epidermis; *h*, hair; *c*, cambium-separating between *p*, phloem and *w*, woody portions of bundles; *v*, spiral vessels in the woody portion; *x*, pith and *y*, common parenchyma of bark; *c*, segment of a sunflower stem; *p*, parenchyma; *b*, bast fibres; *s*, sieve tube; *c*, cambium; *g*, vessels, pitted and spiral; *h*, wood fibres; *d*, one year, and *e*, four year old woody stems, illustrating the increase of vascular bundles. (From Needham's "General Biology" after Wettstein, by permission of The Comstock Publishing Co.)

As no seed can be formed unless the reproductive organs, **stamen** ( ) and **pistils** ( ) are present, these are called **essential organs**, and plants having both essential organs in a single flower are called **perfect flowers**, while those having only **one or the other essential organs**, are called **imperfect.**

If a flower possess, in addition to the essential organs, a **calyx** ( ) and a **corolla** ( ), it is called **a complete** flower.

All of these parts are better understood from a study of Figure 146 than from any description which could be given.

PLANT HISTOLOGY

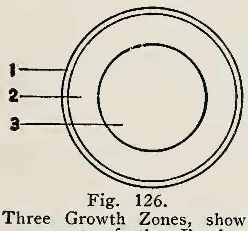


Fig. 126.
Three Growth Zones, showing arrangement of the Fundamental Tissue Layers in roots and stems. 1, Dermatogen zone. 2, Periblem zone. 3, Plerom zone. (After C. W. Ballard's "Vegetable Histology," (Courtesy of John Wiley and Sons.)

A correct understanding of plant tissues can, however, come only from a knowledge of how such tissues develop.

Just as we shall soon see, hydra (because it is composed of tissues only) can regenerate almost any portion of the body, so, too, the early embryonic substance of plants is all quite alike, and can develop into many and varying types of cells. This early undifferentiated embryonic plant tissue is known as **meristem.** It is from this meristem that the so-called **primary tissues** develop. However, in the early embryo, even while all the cells are quite alike, it is possible to suggest a division into three zones (Fig. 126), in each of which certain particular structures will ultimately grow.

The diagram shows an outer, or **dermatogen region**, a more interior, or **periblem region,** and an innermost, or **plerom region.** It is in the dermatogen zone that the **first covering-tissues** develop, while the periblem zone gives rise to the **covering-tissues of the mature plant.** All other structures arise in the plerom zone.

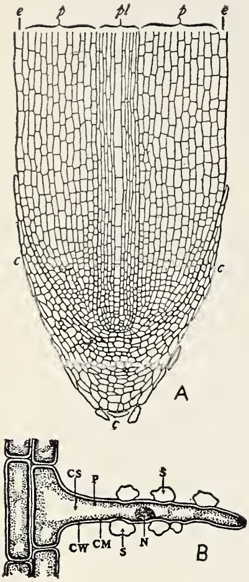


Fig. 127.

A, longitudinal section through the root tip of spiderwort, showing the plerome *(pl),* surrounded by the periblem *(p),* outside of periblem the epidermis *(e)* which disappears in the older parts of the root, and the prominent root-cap *(c).* (After Land.)

B, diagram of a root hair; *CM,* cell membrane; *CS,* cell sap; *CW,* cell wall; *P,* protoplasm; *N,* nucleus; *S,* soil particles.

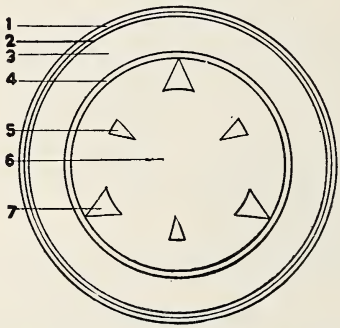


Fig. 128. Arrangement of the Primary Tissues in the Root.

1. Epidermis. 2. Hypodermis. 3. Primary Cortex. 4. Endodermis. 5. Xylem bundle. 6. Pith. 7. Phloem bundle. (After C. W. Ballard's "Vegetable Histology." Courtesy of John Wiley and Sons.)

The original cell-masses which constitute the three zones mentioned above, are known as **fundamental tissues** up to the time the **primary tissues** can be seen.

In the dermatogen of the root, **three distinct primary tissues** develop. The outermost layer at the root-tip (Fig. 127) is the **root-cap.** This becomes thickened and protects the more delicate structures as the process of growth forces the root-cap through the soil.

The epidermal cells above the root-cap give rise to **root-hairs**, which are important **absorption organs.**

Above that portion of the root, which is covered with root-hairs, there are thick-walled epidermal cells. These form the **primary epidermis.**

In the periblem zone there are also three primary tissues. (Fig.

128.) The layer bordering on the primary epidermis is known as the **hypodermis** ( ). This layer is made up of thick-walled cells which are usually angled. The layer joining the plerome zone is the **endodermis** ( ). The cells in this layer are also thick-walled and resemble those of the hypodermal layer. Between hypodermal and endodermal layers there are several layers of cells which constitute the **primary cortex** or **cortical parenchyma** ( ).

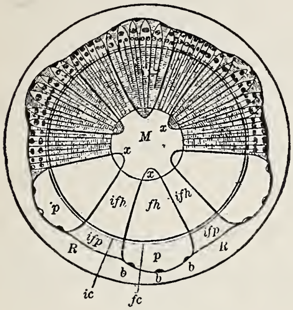


Fig. 129.

Diagram to illustrate secondary growth in a dicotyledonous stem which takes place in the plerome zone.
R, the first-formed bark; *p*, mass of sieve cells; *ifp*, mass of sieve cells between the original wedges of wood; *fc*, cambium of wedges of wood; *ic*, cambium between wedges; *b*, groups of bast cells; *fh*, wood of the original wedges; *ifh*, wood formed between wedges; *x*, earliest wood formed; *(c)*. (After Land.)

The cortical parenchyma is made up largely of undifferentiated original periblem tissue.

It is in the plerom zone (Fig. 129) where the most striking changes in the cell walls take place. Groups of cells have their walls thickened by the deposition of **lignin** ( ), which forms the fibrous elements that give strength to the plant. Such fibrous elements are known as **prosenchyma** ( ). The **conducting elements** are developed in the midst of these lignified cells.

Each group of lignified cells, together with its associated ducts, constitutes the **xylem** ( ). This is usually arranged in a very definite order in the plerom region. There are other cells forming tubes, also in the plerom zone. The end walls of these cells are perforated. These form the **sieve tubes.** Each group of sieve tubes with its associated companion cells, parenchyma cells, and lignified tissues, constitutes the **phloem** ( ). These bundles are also often arranged in a very definite order.

The lignified cells of xylem are called **wood fibers** (Fig. 130), and the lignified cells of phloem are called **bast fibers.**

Xylem and phloem are made up of both **fibrous** and **vascular** (conducting) elements to form **fibro-vascular bundles.**

The xylem and phloem are located in a circle near the outer boundary of the plerom region, and as they begin to develop, usually alternate with one another.

As there are narrow strips of unchanged plerom parenchyma extending between the fibro-vascular bundles (Fig. 131), these strips present the appearance of rays, and consequently are known as

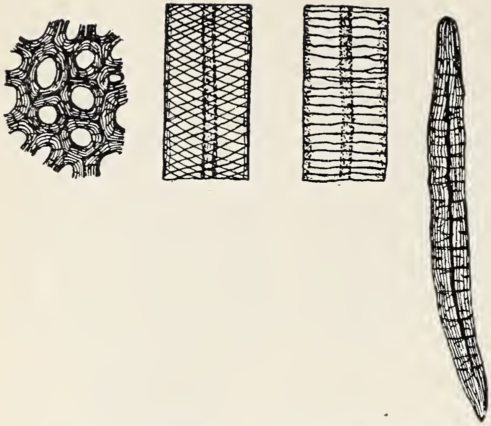


Fig. 130. Types of Wood and Bast Fibers.

A, cross section of bast fibers from stem of *Aristolochia Sipho* showing stratification. *B*, Portion of bast fiber, showing oblique striation. *C*, Portion of bast fiber showing transverse striation. *D*, Bast fiber from the bark of *Cinchona Calisaya*, showing longitudinal striae and small tubes connecting the lumen of the cell with the exterior. (From Bastin's "College Botany." Courtesy of G. P. Engelhard & Co.)

medullary rays, while the unchanged parenchyma in the center of the plerom is the **pith.**

In many orders of plants it is these primary tissues which remain throughout life with but little change, but in the higher orders these primary tissues change to **secondary,** or permanent, tissues. (Fig. 132.)

The epidermis is replaced by a **bark structure** which originates in the periblem region.

Some of the primary cortical cells become meristematic, thus constituting the **cork cambium** or **phellogen** ( ); these cells subdivide rapidly to form a new tissue on their outer surface, the **cork,** and on the inner surface, **phelloderm.**

Bark is everything outside of the true cambium (not the cork cambium), excluding the cambium and epidermis.

The phellogen retains its meristematic power throughout the entire life of the plant so that new protective tissues can keep pace with the internal growth.

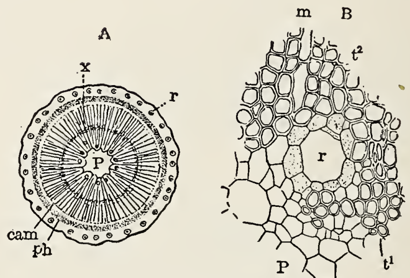


Fig. 131. Medullary Rays and Pith.

A, *Pinus Virginiana*, cross section of two-year-old branch. *P*, pith; *x*, wood, showing two annual rings; *cam*, cambium; ph, phloem; *r*, resin-ducts in the cortex. *B*, *Pinus insignis*, cross-section of the inner part of the wood. *P*, pith; t^1, primary tracheae; t^2, secondary tracheids; *r*, resin-ducts; *m*, medullary ray. (From D. H. Campbell's "A University Text-book of Botany," by permission of The MacMillan Co., Publishers.)

The primary fibro-vascular bundles consist of xylem and phloem, but in the change to secondary structures, a meristematic tissue, called **cambium** ( ), develops in connection with these. The cambium develops on the outer face of the xylem (Fig. 133) and on the inner face of the phloem, so that the cambium arc on each xylem bundle produces xylem on its inner face and phloem on its outer side.[1] Similarly, the cambium arc on the phloem bundle develops xylem on the inner side and phloem upon the outer.

[1]Xylem and phloem both carry water, but the former carries food material as such, while the latter carries food in the water.

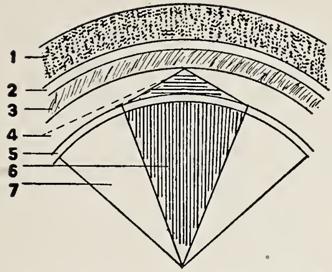


Fig. 132. Arrangement of Secondary Tissues in Roots and Stems.

1. Peridem (bark). 2. Phellogen. 3. Phelloderm (bark). 4. Phloem elements. 5. Cambium. 6. Xylem elements. 7. Medullary rays. Compare with Fig. 129. (After C. W. Ballard's "Vegetable Histology." Courtesy of John Wiley and Sons.)

This causes each fibro-vascular bundle now to consist of xylem and phloem elements, separated from each other by a thin strip of cambium. Such bundles, which have been completed by the cambium, are called **complete fibro-vascular bundles,** while those not so completed are known as **incomplete fibro-vascular bundles.** (Fig. 134.)

As the cambium continues to grow constantly, the plerom parenchyma becomes almost entirley replaced by xylem. The new fibro-vascular bundles develop in the broad primary medullary rays.

The stem and root development differ somewhat. There are no root hairs or root-caps on the stem. The primary stem epidermis often possesses **stomata** (breathing pores), while the root does not. The parenchymal cells of the stem often contain **chloroplasts** which the parenchymal cells of the root never do. Then, too, the root has no hypodermis (mechanical tissue immediately underneath the epidermis). There is usually no endodermis in the stem, though there is in the root. The plerom zone of primary stems differs considerably from that of primary roots both in the arrangements and development of tissues. All fibro-vascular bundles in the plerom region of the primary stem are complete, showing phloem, xylem, and cambium elements throughout their entire period of growth. This means that the primary fibro-vascular bundles of the stem are really equivalent to the secondary bundles of the root. The primary stem structures, described above, serve throughout the life of the plant only if such plant is an **annual.** In **perennials** ( ), a better and more durable covering tissue must be developed. In these, the primary epidermis is replaced by periderm tissues which have been produced by a phellogen which in turn developed in the primary cortex. The peri-

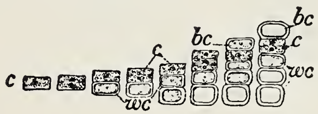


Fig. 133. Diagram Showing the Method by which the Cambium Layer Produces Wood Cells on its Inside and Bark Cells on the Outside.
bc, the cells of the bark; *c,* cambium cells; *wc,* the wood cells.

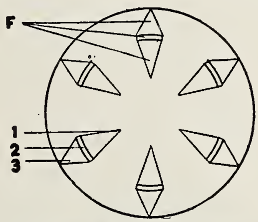


Fig. 134. Completion of Fibrovascular Bundles.
F, Completed fibrovascular bundle. 1. Xylem elements. 2. Cambium. 3. Phloem elements. (From C. W. Ballard's "Vegetable Histology," Courtesy of John Wiley & Sons.)

derm of stems is often ruptured and cast off as the inner tissue expands. This does not occur in roots. When such casting off takes place, the primary periderm is replaced by secondary periderm which develops directly from the original phellogen or secondary phellogen layers. The hypodermal and endodermal layers disappear as soon as the phellogen is formed in the primary cortex. The primary fibro-vascular bundles become larger by new xylem and phloem elements added by the cambium, and the cambium arcs extend until they become a complete ring or circle.

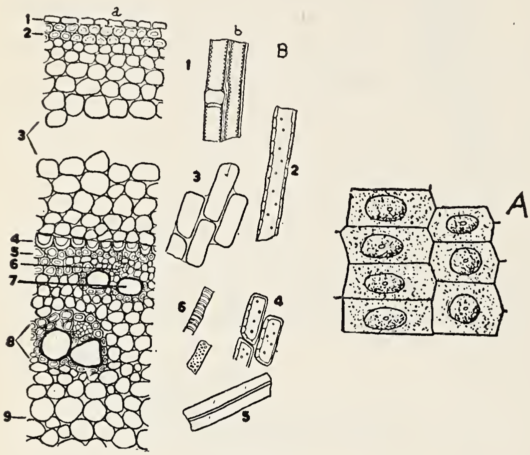


Fig. 135.

A. Early undifferentiated cells known as Embryonic or Meristem tissue

B. The secondary (permanent) tissues are divided into parenchyma and prosenchyma. The former have thin walls and protoplasmic contents. They are found in the undifferentiated cellular structures of all three zones in the embryo. They are usually spherical in shape, or at least "as broad as they are long." Prosenchyma cells are formed in the Plerom region of the embryo. They have thick walls and little or no cell content. The cells are usually long fiber cells with sharp-pointed ends.

a. Transverse Section, *Triticum* Rhizome. 1. Epidermis. 2. Hypodermis. 3. Cortical parenchyma. 4. Endodermis. 5. Fibers, surrounding sieve and ducts. 6. Sieve. 7. Ducts. 8. Concentric fibrovascular bundle. 9. Pith parenchyma.

b. Powdered *Triticum* Rhizome. 1. Epidermis. 2. Hypodermis. 3. Parenchyma, longitudinal view. 4. Endodermis. 5. Fibers. 6. Vessels. (From C. W. Ballard's "Vegetable Histology," Courtesy of John Wiley & Sons.)

New fibro-vascular bundles form in the broad medullary rays extending between the original bundles, while new woody elements are being added to the xylem. These woody elements, however, never entirely replace the original plerom tissue in the center of the stem. This unchanged central plerom tissue is the **pith.** As the plerom parenchyma is entirely replaced by woody tissues in roots, the presence of pith is valuable in distinguishing stem from root.

The secondary or permanent stem tissues are often divided into **parenchyma** ( ) and **prosenchyma. Parenchymal cells** may be found in all three zones of the embryo. They have thin walls and protoplasmic contents. **Prosenchymal cells** are formed in the plerom region of the embryo. They have thick walls, and the protoplasmic contents are very inconspicuous or even entirely lacking. While these distinctions are by no means absolute, they are of great importance. Further, prosenchymal cells are usually spindle-shaped, while parenchymal cells are more inclined to be spherical or cubical with rounded corners. (Fig. 135.)

The final tissues are usually grouped according to their functions. They are:

Covering or **Protective Tissues.** (Fig. 136.) **Epidermis** and **periderm.**

Supporting or **Mechanical Tissues.** (Fig. 137.) All fibrous tissues, such as wood and bast fibers, stone cells **(sclerenchyma)**, polygonal cells with very thick cellulose walls, especially thick at the angles **(collenchyma)** which take the place of woody tissue in annual herbaceous or green stems, fruits, seeds, and leaves. Collenchyma is usually associated with the fibrous tissues in the midrib of leaves.

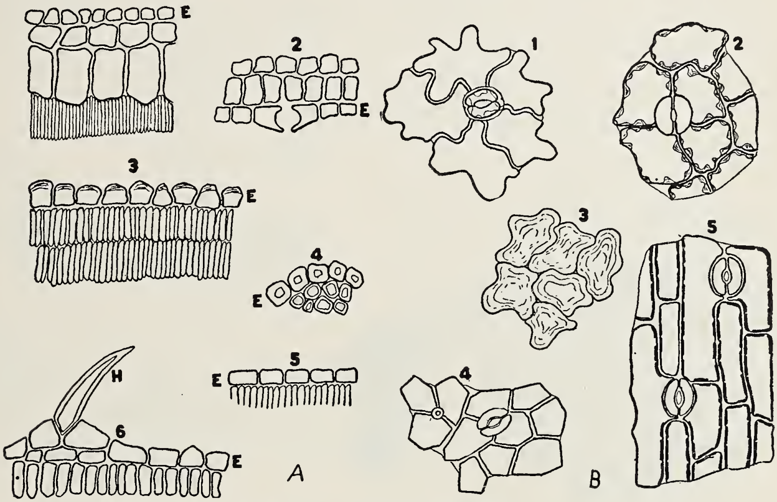


Fig. 136. Epidermal Tissues.

A, Sectional views of Leaf Epidermis. 1. Upper epidermis, *Ficus* leaf. 2. Lower epidermis, *Ficus* leaf. 3. Upper epidermis, *Eucalyptus* leaf. 4. Epidermis of Pine leaf. 5. Upper epidermis, Orange leaf. 6. Upper epidermis, Geranium *(Pelargonium),* leaf. *E,* epidermis. *H,* hair.

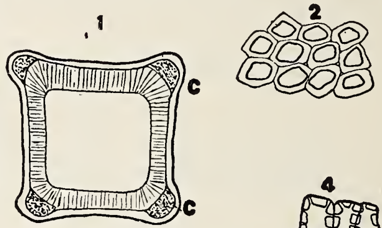
B, Surface views of Leaf Epidermis. 1. *Hepatica* leaf (wavy walls). 2. *Chimaphilla* leaf (beaded walls). 3. Henbane leaf (wavy and striated walls). 4. Senna leaf (angled cells). 5. *Convallaria* leaf (beaded walls). (From C. W. Ballard's "Vegetable Histology," courtesy of John Wiley & Sons.)

Absorption Tissues. (Fig. 138.) Root-hairs for liquids, and **stomata** (openings usually on the underside of leaves surrounded by two sausage-shaped guard-cells) and **lenticels** (openings in the periderm or corky coverings of mature woody plants.)

Conducting Tissues. (Fig. 139.) This consists of ducts known as **tracheae** if they are continuous tubes formed by the absorption of the connecting cell's end-walls, and there is a disappearance of the cell contents. These tubes may be **pitted** (when there are numerous pores through the cell wall), **reticulate** (when the lignin laid down on the inner side of the cell wall is in the shape of a network), **scalariform** (when the non-lignified portions of the cell walls form long narrow slits which are quite uniform). Such cells are often angled (no others are). **Annular** (thin-walled tubes with rings of lignified tissue within the lumen of the tube), and **spiral** (where the lignified tissue is arranged in the form of a continuous spiral-band, or collection of bands).

Tracheids are merely single cells which have lost their protoplasmic contents, but not their entire end-walls. Communication is carried on by pores in the vessel walls.

Sieve Tubes, unlike all the other ducts mentioned above, usually carry materials away from the leaves. They are merely individual cells whose end-walls have not completely broken down, as in the tracheids, but have formed sieve plates with many pores or perforations connecting one such individual cell with the next below, and so continuing for great lengths in the plant. The walls of sieve tubes are composed of cellulose, without a trace of lignification.



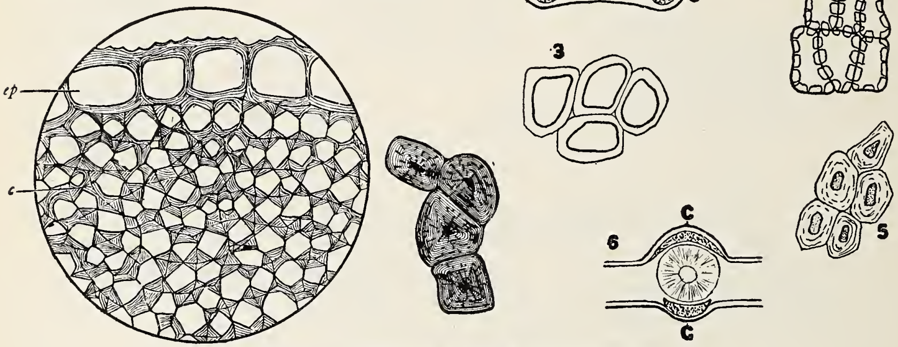


Fig. 137. Mechanical and Supporting Tissues.

These tissues consist of wood and bast fibers (See Fig. 130, *sclerenchyma* (stone-cells), and *collenchyma*.

A, Portion of epidermis and collenchyma from the stem of *Rumex crispus*. Cross section, *ep*, epidermis; *c*, collenchyma.

B, Sclerotic cells from the root of *Apocynum androsaemifolium*. All highly magnified. (From Bastin's "College Botany," courtesy of G. P. Engelhard & Co.)

C, 1. Peppermint stem. Arrangement of collenchymatic *(C)*, tissues at angles of the stem. 2. Peppermint stem. 3. Sabal seed. 4. Colchicum seed. (Porous type.) 5. Nux Vomica seed. (Striated type.) 6. Arrangement of collenchymatic tissues around the midvein of a leaf. *C*, collenchyma. (From C. W. Ballard's "Vegetable Histology," Courtesy of John Wiley & Sons.)

Medullary Rays furnish the means by which material is transported laterally from the inner-tube region of the plant to the tissues which lie closer to the outside of the stem, and from these to the pith where food may be stored.

Latex Tubes. These are non-porous tubes in certain plants and contain a milk-like fluid.

Porous Parenchyma. In the pith region, the parenchyma, which is very porous, may possibly assist in permitting the nutrients in solution to pass back and forth.

As already stated, each group of vessels with its connecting mechanical or supporting tissue, forms a fibro-vascular bundle. These may be either complete or incomplete; complete, if they possess xylem, phloem, and cambium elements; and incomplete, if they possess either xylem or phloem without the cambium element. The xylem is always supported by wood fibers and the phloem by bast fibers. There are five different arrangements of fibro-vascular bundles:

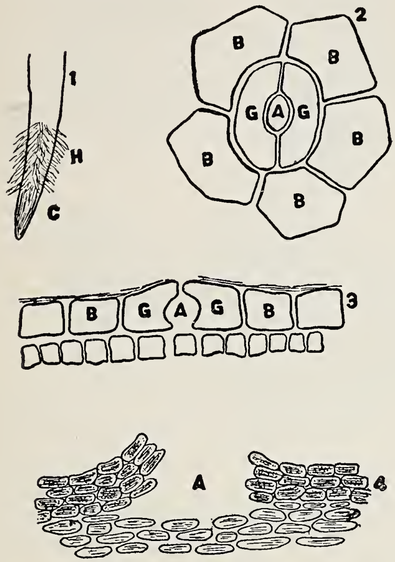


Fig. 138. Absorption Tissues.

1. Root hairs *(H)* on rootlet of germinating Fenugrek seed. *C*, root cap. 2. Stomata, surface view. *A*, breathing pore. *G*, guard cells. *B*, bordering, neighboring or surrounding cells. 3. Stomata, sectional view. *A*, breathing pore. *G*, guard cells. *B*, bordering cells. 4. Lenticel *(A)*. (From C. W. Ballard's "Vegetable Histology," Courtesy of John Wiley & Sons.)

(1) **Radial** (common in all young roots, and sometimes in mature monocotyledonous roots). These are always incomplete, consisting of either xylem or phloem. The xylem or phloem elements are arranged in a circle within the endodermis, a xylem bundle alternating with a phloem bundle.

(2) **Concentric fibro-vascular bundles** (common in monocotyledonous roots and stems), are bundles consisting of both xylem and phloem, so arranged that either the xylem surrounds the phloem or the phloem surrounds the xylem. The former arrangement is the more common. The bundles are irregularly scattered in the pith region.

(3, 4, and 5) **Collateral fibro-vascular bundles** are complete, having both xylem and phloem elements, as well as a cambium-arc. These are in turn divided into three types, known as **open, closed,** and **bi-collateral.**

(3) **Closed Collateral bundles** (usually found only in the pith of monocotyledonous stems and rhizomes and in the leaves of all seed plants), are made up of a xylem portion and a phloem portion, never separated from each other by a strip of cambium.

(4) **Open Collateral bundles** (most frequently found in dicotyledonous roots and stems) are made up of xylem elements with a cambium zone and phloem elements on the outer side of the cambium.

(5) **Bi-Collateral bundles** (found in some dicotyledonous roots and stems) are made up of a xylem element and the associated cambium, but with two phloem elements, one on each surface of the xylem.

Assimilating and Synthesis Tissues (Fig. 140). The Chloroplasts

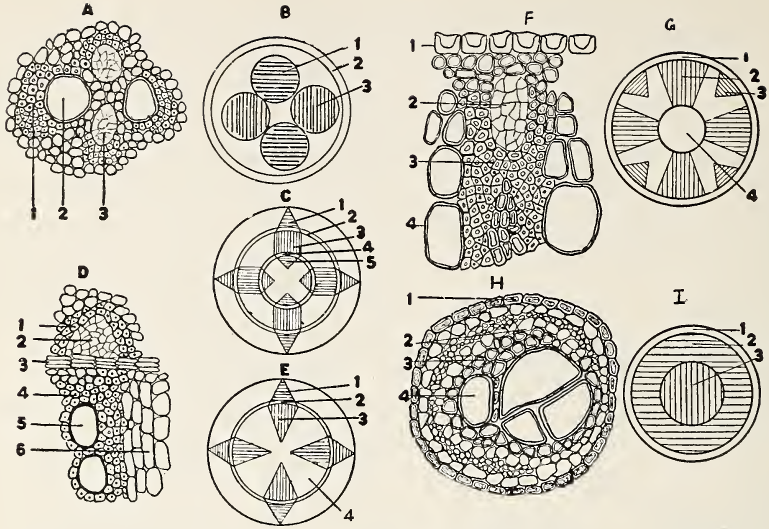


Fig. 139. Conducting Tissues.

A. Collateral type, Bamboo stem. 1. Fibrous tissue. 2. Ducts. 3. Sieve.
B. Collateral Bundle arrangement of fibrovascular elements. 1. Xylem. 2. Endodermis. 3. Phloem.
C. Bicollateral Bundle arrangement of fibrovascular elements. 1. Phloem. 2. Cambium. 3. Xylem. 4. Cambium. 5. Phloem.
D. Open collateral type, Aconite tuber. 1. Bast fibers. 2. Sieve cells. 3. Cambium. 4. Wood fibers. 5. Ducts. 6. Medullary ray.
E. Open Collateral Bundle arrangement of fibrovascular elements. 1. Phloem. 2. Cambium. 3. Xylem. 4. Medullary ray.
F. Radial type, Sarsaparilla root. 1. Endodermis. 2. Sieve surrounded by bast fibers. 3. Wood fibers surrounding sieve and ducts. 4. Ducts.
G. Radial Bundle arrangement of fibrovascular elements. 1. Endodermis. 2. Xylem. 3. Phloem. 4. Pith.
H. Concentric type, Fern rhizome. 1. Endodermal sheath. 2. Sieve surrounded by small parenchyma. 3. Fibrous tissues. 4. Ducts.
I. Concentric Bundle arrangement of fibrovascular elements. 1. Endodermal sheath. 2. Phloem. 3. Xylem. (From C. W. Ballard's "Vegetable Histology," Courtesy of John Wiley & Sons.)

(the tiny divisions in the cell of plants which contain chlorophyl), are important structures in synthesis by converting (when in the sunlight) carbon dioxide and other substances into starches and sugars; and the **Leukoplasts** (similar structures which do not contain chlorophyl), by assisting in forming storage or reserve-starch from the sugar manufactured by the chloroplasts.

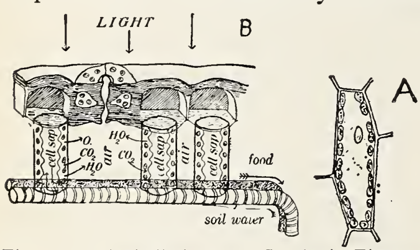


Fig. 140. Assimilating and Synthesis Tissues.
A. Plastids (chloroplasts) in a cell.
B. Diagram to illustrate the processes of breathing, food-making, and transpiration which may take place in the cells of a green leaf in the sunlight. (After Stevens.)

Secreting cells and hairs which are really structures quite like the glands of animals.

Storage Tissues (Fig. 141). In plants which continue their life throughout many seasons, there must be a method of storing the food which is made primarily in the summer. The organs are the **Parenchyma cells** of the cortical and pith regions. Here the reserve starch made by the leukoplasts is stored, as also are many other plant nutrients.

Secretion cavities of various kinds carry oils and other products of gland cells.

Collenchyma cell walls, especially in seeds and fruits, contain much cellulose. This means that collenchymal cells are both supporting and storage tissue as well as synthesis tissue.

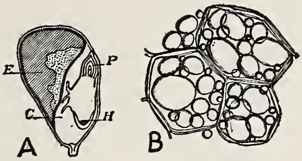


Fig. 141. Storage Tissues.

These are the parenchyma cells of the cortical and pith regions of the plant; the cellulose in the collenchyma cells (which makes collenchyma a synthesis, supporting, and storage tissue), and cavities of stone cells and fibers.

A, grain of corn, cut lengthwise; *C,* cotyledon; *E,* endosperm; *H,* hypocotyl; *P,* plumule.

B, starch grains in the cells of a potato tuber.

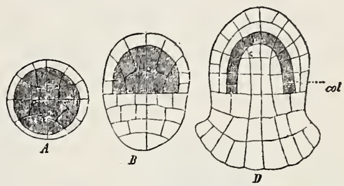


Fig. 142. Reproductive Tissues.

Diagrammatic sections of sporogonia of liverworts: *A, Riccia,* the whole capsule being archesporium except the sterile wall layer; *B, Marchantia,* one half the capsule being sterile, the archesporium restricted to the other half; *D, Anthoceros,* archesporium still more restricted, being dome-shaped and capping a central sterile tissue, the columella *(col).* (After Goebel.)

Cavities of stone cells and fibers may contain nutrient material in a few cases, but in such instances it is not readily available for the plant.

Reproductive tissue (Fig. 142). From inner tissues of anther and ovary in flowering plants.

When pollen is transferred from **anther** ( ) to **stigma** ( ) the process is called **pollination. Wind, insects,** and **water** are means by which **pollen is carried** from one plant to another. Bees are common carriers, and the remarkable way some plants are adapted to forcing any intruder to carry pollen with it, is one of the most astounding of all adaptations in nature (Fig. 239).

POLLINATION

Pollination can probably best be understood by considering the modern pines. In the common Scotch pine (Fig. 143), **(Pinus silvestris)** the **microsporophyls** (called **stamens** in the flowering plants) are massed into cones about one centimeter in length, and these cones are in turn massed in clusters.

There are two sporangia on the lower surface of each microsporophyl. These **microspores,** or **pollen,** escape from the sporangia and are carried by the wind (often for many miles) to the **megaspore** (carpellate) **cones.**

The megaspore cones grow singly or in clusters near the ends of the upper twigs of the season's growth, and are also about one centimeter in length. There is a general axis on which flat megasporophyls are borne. Each of these megasporophyls bears two inverted **megasporangia** or **ovules** (Fig. 144).

The pollen falls between the **megasporophyls** (called **carpels** in the flowering plants), and each microspore then pushes out a **pollen tube** which penetrates the ovule tissue. This process stimulates the growth of the cone tissues, and the cone, therefore, increases in size. The ovules also enlarge, and the upper end of the ovule develops a thickened mass of green tissue which grows beyond the end of the sporophyl, to form the **seed scale.** These seed scales are merely the distal ends of the ovules, and function as organs of photosynthesis for a year or so.

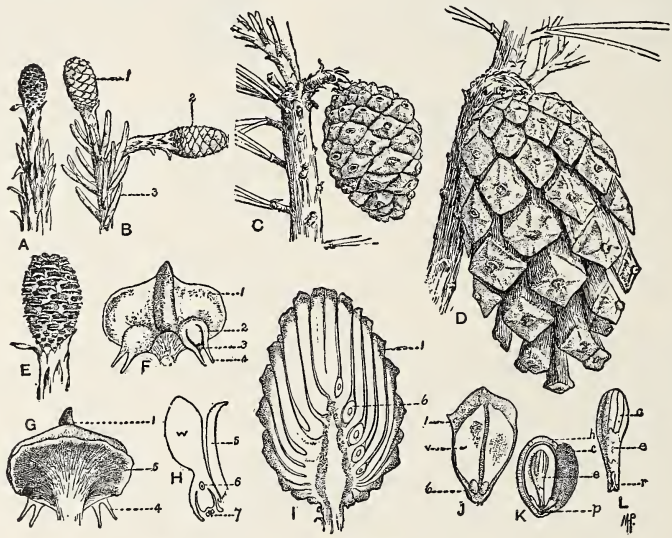


Fig. 143. Scotch Pine *(Pinus sylvestris).*

A-D, stages in the development of the carpellate cone, and its carpotropic movements. *E,* very young carpellate cone much enlarged; *F,* vetral, *G,* dorsal views of a scale from *E;* 1, ovuliferous scale; 2, ovule (in logitudinal section); 3, pollen chamber and micropyle leading to the apex of the nucellus (megasporangium); 4, integument of the ovule; *G,* 1, tip of ovuliferous scale; 5, bract; 4, integument; *H,* longitudinal section at right angles to the surface of the ovuliferous scale (diagrammatic); 6, megaspore; 7, pollen chamber, *I,* longitudinal section of a mature cone; 6, ovule; *J,* scale from a mature cone; 6, seed; *w,* wing of seed; *K,* dissection of mature seed; *h,* hard seed coat; *c,* dry membranous remains of the nucellus, here folded back to show the endosperm and embryo; *e,* embryo; *p,* remains of nucellus; *L,* embryo; *c,* cotyledons; *e,* hypocotyl; *r,* root-end. (From C. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Son & Co., Publishers.)

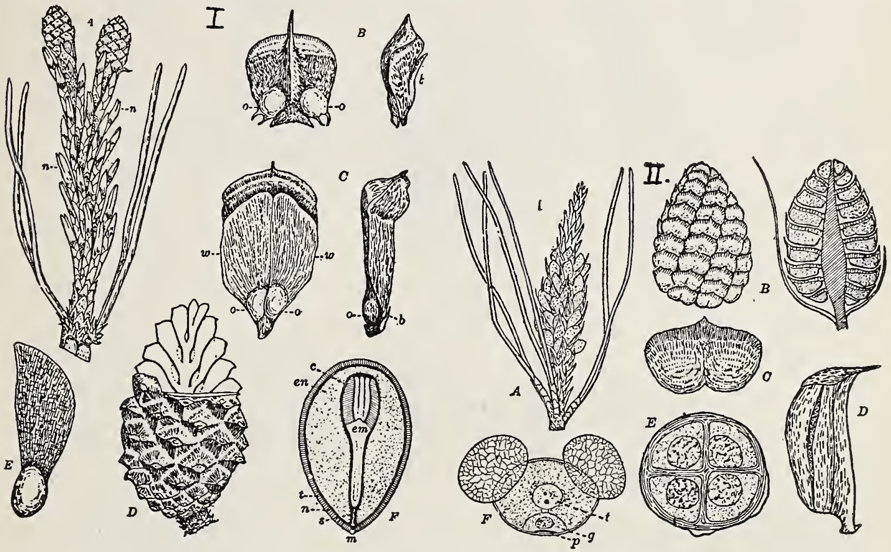
The following summer or autumn a **spore-mother-cell,** also known as an **archespore,** arises in the interior tissues of the ovule. This archespore then divides into four cells which are really four young megaspores, although only the one lying in the lowest position actually develops into a full-fledged megaspore.

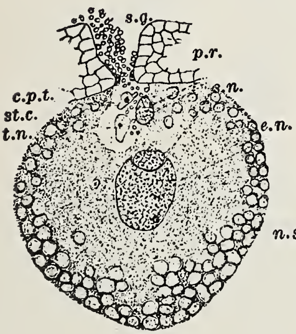
This megaspore then divides and subdivides until a rather solid cellular mass is formed. This cellular mass is the **gametophyte.** (Fig. 145.)

It is from this gametophyte that several (usually four) sunken archegones arise. The completing process of fertilization may now take place.

After fertilization the gametophyte becomes stored with food and functions as the **endosperm.**

The pollen-tube has also resumed its growth by this time and has





III

Fig. 144. I. Carpellate cone, carpels, and seed of the Scotch pine *(Pinus sylvestris).*

A, young growth with carpellate cones, about three weeks after the opening of the terminal bud: *n,* young pine needles. *B,* inner and side view of a cone scale at the time of pollination as shown in *A: b,* bract; *o,* ovules. *C,* inner and side view of scales from a mature cone as shown in *D: b,* bract; *o,* fertilized ovules now rapidly maturing into winged seeds; *w,* the developing wings. *D,* a mature cone. *E,* a mature winged seed. *F,* section of mature seed; *t,* hard seed coat, or testa, developed from the integument of the ovule, *n,* a membranous seed coat which is the remains of the nucellus; *en,* endosperm or tissue of the female gametophyte; *em,* embryo with group of cotyledons *c* and the suspensor *s; m,* micropylar end of seed.

II. The staminate cone, stamen, and pollen of the Scotch pine *(Pinus sylvestris).*

A, young growth, with staminate cones about two weeks after the opening of the terminal bud. *B,* details of cone. *C,* end view of stamen. *D,* side view of stamen. *E,* pollen mother cell developing four pollen grains in a tetrad. *F,* pollen grain showing the two wings; *p,* prothallial cell; *g,* generative cell; *t,* tube nucleus.—*E,* (After Miss Ferguson).

III. White pine.

(Pinus Strobus.) Longitudinal section through an archegonium at the time of fertilization. Above the fusing nuclei are various other elements emptied into the egg from the pollen-tube. Collected June 21, 1898. × about 62. *s.g.,* starch grains; *p.r.,* prothallium; *c.p.t,* cytoplasm from pollen-tube; *st.c.,* stalk-cell; *t.n,* tube-nucleus; *s.n,* sperm-nucleus; *e.n,* egg-nucleus; *n.s,* nutritive spheres. (After Margaret C. Ferguson.) I, II, (From Bergen & Davis "Principles of Botany," by permission of Ginn & Co., Publishers). III, (From C. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Son & Co., Publishers).

brought the two non-ciliated sperm to the mouth of an archegone. One of the sperm fuses with the egg which completes fertilization. This fertilization takes place in the pines more than a year after pollination.

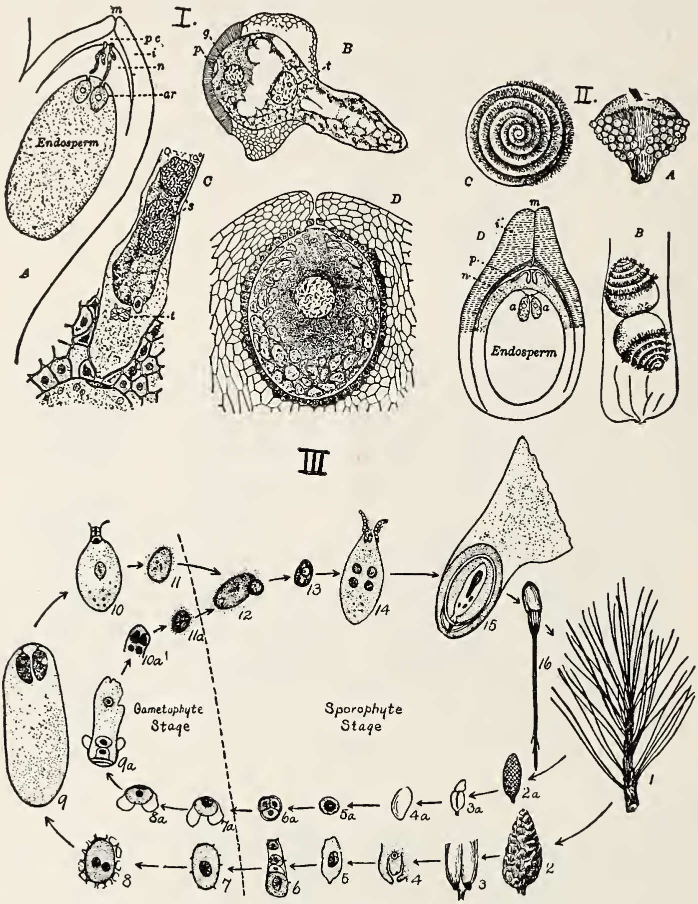


Fig. 145. I. The Gametophytes of the Pine.

A, diagram of a section of a year-old ovule; embryo sac with mature archegonia *ar* imbedded in the tissue of the *endosperm* (female gametophyte); pollen tubes (male gametophytes) growing down through the tissue of the nucellus *n; p c,* pollen chamber; *m,* micropyle; *i,* integument. *B,* germinating pollen grains, showing young male gametophyte; *t,* tube nucleus; *g,* generative nucleus; *p,* prothallial cell. *C,* tip of pollen tube applied to the egg; *t,* tube nucleus; *s,* the two sperm nuclei. *D,* a mature archegonium sunken in the tissue of the endosperm, showing the large egg surrounded by a jacket of cells rich in protoplasm: two neck cells of the archegonium shown just above the egg.—*B, C,* (After Miss Ferguson).

II. The Sperm and Ovule of a Cycad *(Zamia).*

A, lower surface of a stamen, with numerous pollen sacs in two groups. *B,* the two large top-shaped motile sperms at the end of the pollen tube ready to be discharged above the archegonia. *C,* a sperm viewed from the end, showing the spiral band which bears the cilia. *D,* diagram of a section of an ovule after pollination; *m,* micropyle; *i,* integument; *p,* pollen chamber; *n,* nucellus containing developing pollen tubes; *a,* archegonia, with large eggs imbedded in the endosperm (female gametophyte).—*B, C,* (After Webber).

III.—Diagram of the life-cycle of a pine. (After Schaffner.)

I., II., (From Bergen & Davis "Principles of Botany," by permission of Ginn & Co., Publishers).

The fertilized egg, now called a **zygote**, gives rise to the **embryo** which consists of a cylindrical stem with narrow whorled leaves and a root. It is still imbedded in the gametophyte tissue from which it draws its nourishment.

The ovule, seed-scale, and cone have increased in size in the meantime, and the seed-scales lose their chlorophyl and become woody. As the supply of water becomes less and less the cone becomes dry, and consequently the young sporophyte stops growing. The cone and seeds are now said to be **ripe**, so that as the dry seed scales are spread out and blown away, the part of the seed which contains the embryo, is carried with them. As soon as water is again supplied, the embryo again begins to grow, breaking the brittle **integument** or **indusium** covering it, and the root is ready to penetrate the soil and carry water to the stem and leaves of the new plant.

FLOWERS

The flowers of flowering plants (Fig. 146) consist of cone-like clusters of closed megasporophyls **(carpels)** above, and microsporophyls **(stamens)** below, subtended by a **perianth.** The plant on which the flowers grow is the **sporophyte.**

The microspores or pollen-cells (Fig. 147), each produce a mature gametophyte which consists of a pollen tube with three nuclei (Fig. 148 B); one, the nucleus of the pollen tube itself, and the other **two, sperm nuclei.**

The megaspore is retained within the ovule (Fig. 148 A), **(megasporangium).** A gametophyte with a single egg develops within the ovule. After fertilization, the zygote develops into an **embryo** and an **endosperm,** to be described shortly, while the entire ovule becomes covered with one or two coats to form the seed. With proper moisture and soil, the sporophyte escapes from the seed as with the pine. (Fig. 149.)

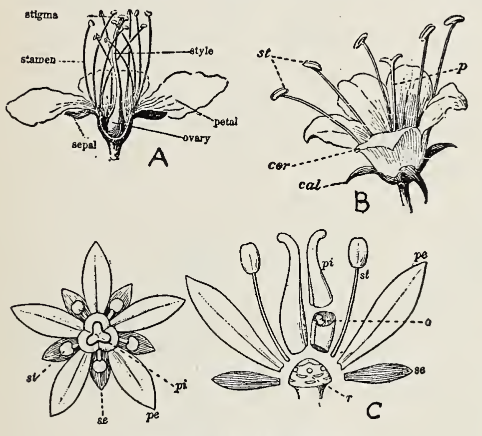


Fig. 146. Floral Organs.

A, Orange blossom.. (After Bailey.)

B, Hydrophyllum, cal, lobe of calyx; *cor,* lobe of corolla; *st,* stamens; *p,* pistil. (After Lindley.)

C, Diagrams of flower, showing face-view and dissection. *r,* receptacle; *se,* sepal; *pe,* petal; *st,* stamen; *pi,* pistil; *o,* ovule.

The parts of a complete bisexual flower of the higher seed plants (angiosperms) are *sepals, petals, stamens,* and *pistils.* The sepals, taken together, constitute the *calyx;* the petals, taken together, constitute the *corolla.* The calyx and corolla are collectively known as the *floral envelopes,* or *perianth.*

Many angiospermous flowers consist of five circles, or whorls, two of which belong to the perianth, two to the stamens, and one to the pistils. The parts of each circle alternate in position with those of the preceding or following one, and all the members of each circle are alike. (From Bergen & Davis "Principles of Botany," by permission of Ginn & Co., Publishers.)

The purpose of a flower is the production of seed. The ripened carpel, with its contained seed, is known as a **fruit.** (Fig. 150.)

The buttercup (Fig. 151) will serve as an excellent example of the flowering plants. Here we have many carpels (simple pistils) each made up of an ovary (the simple closed cavity below) which gradually tapers to a soft terminal **stigma.** The carpels are flat and open when the plant is young, but they gradually have their margins curve upward and close. During the time the carpel is closing, an ovule grows out from the base and becomes enclosed by the carpel walls.

There are several rows of stamens encircling the pistils. Each stamen or microsporophyl bears four elongated, parallel, sporangia containing **pollen** or **microspores.** The stalk of the stamen is called the **filament,** while the four **pollen-sacs (sporangia)** are known collectively

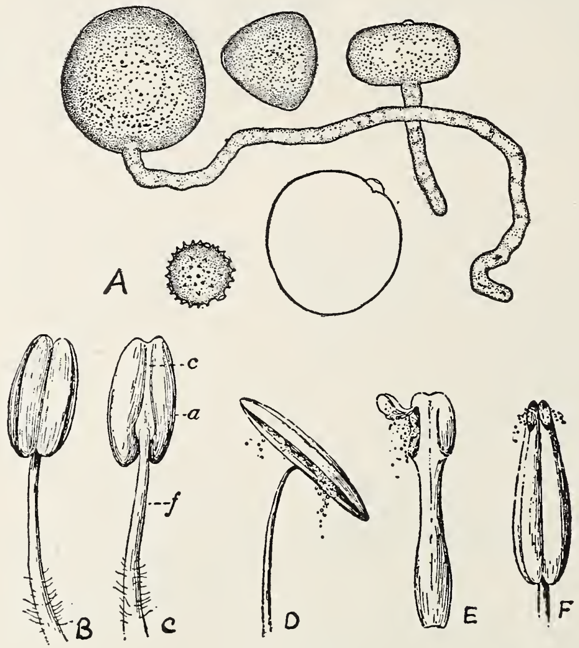


Fig. 147.

A. Different kinds of pollen grains, highly magnified, two of them forming tubes. (After Duggar.)
B, C. Parts of a stamen.
A, front; *B,* back; *a,* anther; *c,* connective; *f,* filament. (After Strasburger.)
D, E, F, Modes of discharging pollen.
A, by longitudinal slits in the anther cells (amaryllis); *B,* by uplifting valves (barberry); *C,* by a pore at the top of each anther lobe (nightshade). (After Baillon.)

as the **anther.** When mature, the sporangia split longitudinally and permit the escape of the pollen.

There are two series of leaf-like structures below the structures we have just been discussing. These two series together form the **perianth.**

The upper series is made up of yellow **petals.** The petals collectively form the **corolla.** The lower series consists of five pointed, green **sepals,** and collectively forms the **calyx.**

A **spore-mother-cell,** or **archespore,** arises in the ovule (Fig. 148A). This then divides into four young **megaspores,** only the deeper one developing. The other three perish. There is thus **only a single megaspore in the ovule.** The nucleus of the megaspore later divides into two, each portion moving toward opposite poles of the megaspore cavity. Each of these portions divides twice, thus forming four nuclei at each pole.

One nucleus from each pole (often called the **polar nuclei**) then moves toward the center and these two meeting, unite.

One of the nuclei about the pole functions as an egg nucleus. The two companion cells are called **synergids.** The cells at the opposite pole are called the **antipodal cells.**

It is at this time that the pollen, which has fallen on the carpel

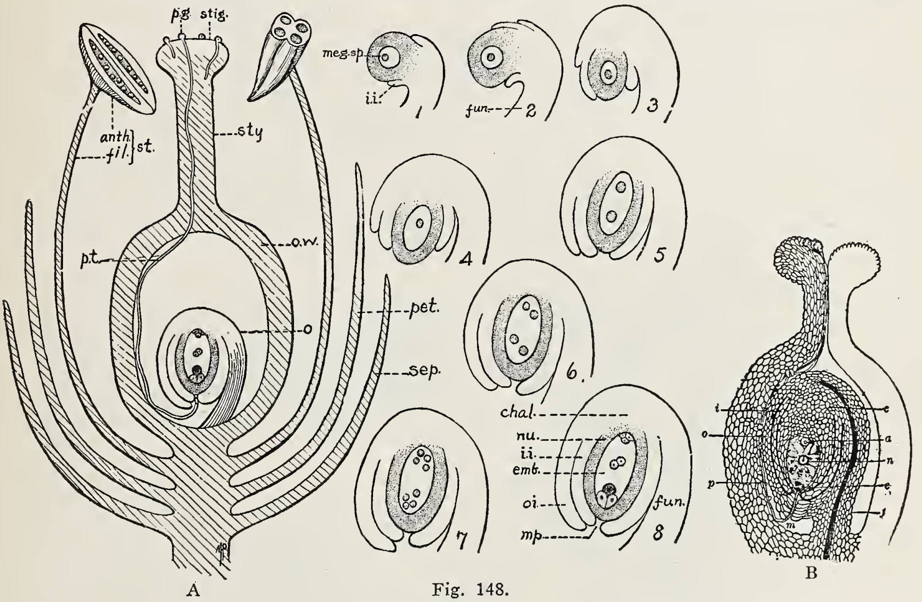


Fig. 148.

A. At the left, diagram of the anatomy of an angiospermous flower shortly after pollination; *anth.*, anther; *fil.*, filament; *st.*, stamen; *stig.*, stigma; *p. g.*, pollen grains germinating; *sty.*, style; *pt.*, pollen tube; *o. w.*, ovary wall; *o.*, ovule, containing embryo-sac; *pet.*, petal; *sep.*, sepal. 1-8, Stages in the development of the female gametophyte (embryo-sac); *meg.sp.*, megaspore-mother-cell; *i.i.*, inner integument; *o.i.*, outer integument; *fun.*, funiculus; *chal.*, chalaza; *nu.*, nucellus (megasporangium); *emb.*, embryo-sac. All diagrammatic. (From C. Stuart Gager's "Fundamentals of Botany," by permission of P. Blakiston's Son & Co., Publishers.)

B. Diagrammatic Representation of Fertilization of an Ovule.

i, inner coating of megasporangium (ovule); *o*, outer coating of ovule; p, pollen tube proceeding from one of the pollen grains on the stigma; *c*, the place where the two coats of the ovule blend. (The kind of ovule here shown is inverted, its opening *m* being at the bottom, and the stalk *f* adhering along one side of the ovule.) *a* to *e*, embryo sac, full of protoplasm; *a*, so-called antipodal cells of embryo sac; *n*, central nucleus of the embryo sac; *e*, nucleated cells, one of which, the egg cell, receives the male nucleus of the pollen tube; *f*, funiculus or stalk of ovule; *m*, micropyle or opening into the ovule.—(After Luerssen.)

stigma, **germinates** to produce a reduced gametophyte and a pollen tube. This pollen tube penetrates the soft stigma tissues and carries two sperm toward the ovary cavity. As the pollen tube reaches the ovule, it enters a tiny pore, called the **micropyle**, between the two integuments, and then passes through the nucellus. The ovule is thus penetrated, and one of the sperm unites with the egg and fertilizes it.

The zygote now divides continually, and soon there is developed a

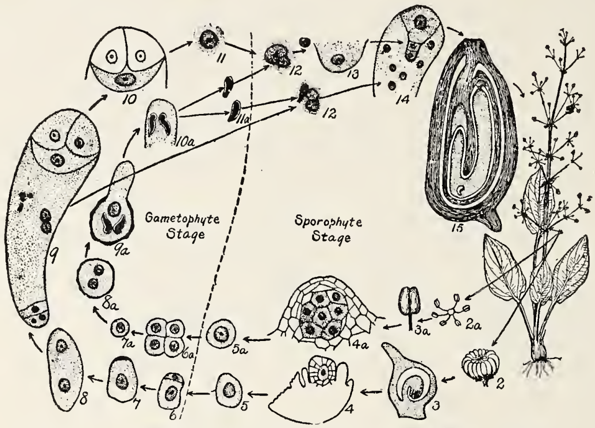


Fig. 149. Diagram of Life-cycle of an Angiosperm *(Alisma Plantagoaquatica).*
9, female gametophyte (embryo-sac); 8*a* and 9*a*, male gametophyte (pollen-grain). (After J. H. Schaffner.)

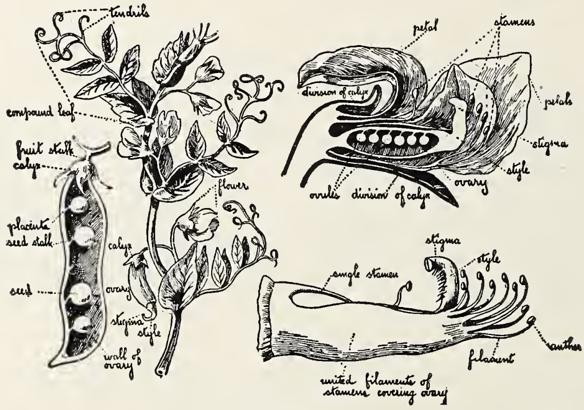


Fig. 150.
Development of the pea fruit from the pea flower. (After Yung's Chart.)

tiny stem with a little root at one end and two rudimentary leaves at the other.

The gametophyte has, in the meantime, resumed its development, due to the union of the second sperm nucleus with the two polar nuclei, to form the endosperm nucleus. This endosperm nucleus divides rapidly, although the cell walls are much delayed in this development.

In a short time the endosperm has surrounded the embryo sporophyte and has filled in the growing ovule. This surrounding and nourishing cell mass is now called the **endosperm,** which is neither **gametophyte** nor sporophyte.

As the ovule grows in size, its outer coat becomes thickened and hardened, and the endosperm within enlarges and solidifies. A layer of cells at the base of the ovule now becomes corky and checks the supply of water, so that the whole ovule becomes hardened to form the **seed.**

It will be noted, therefore, that the spermatophytes also show an alternation of generations, the ordinary plant being the sexless type. It is this ordinary flowering plant which produces the microspores, or pollen grains, and megaspores. In the nuclear divisions which produce these cells, the **chromosome number is reduced to half the original number.**

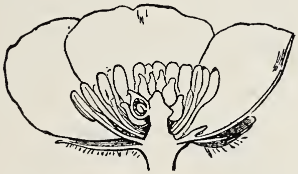


Fig. 151.
Median section of the flower of a Buttercup showing its constitutent parts. On the outside (lowest down in the figure and shaded) are the sepals of the calyx: within this the large petals of the corolla of which three are shown; within this and seated higher on the axis are the numerous club-shaped stamens, each of which bears four pollen-sacs. Centrally in the flower are the numerous carpels, one of which is dissected so as to show its single ovule, or future seed. (From Bower after Le Maout and Decaisne.)

The **pollen grains produce one of the sexual phases** of the life history, the male gametophyte, which forms the sperm nuclei; the megaspore **produces the other sexual phase, the female gametophyte** which bears an egg. Fertilization occurs by the fusion of a sperm cell with the egg; thus **the nucleus of the fertilized egg contains twice the number of the reduced amount of chromosomes,** one-half of which has been contributed by the sperm and one-half by the egg. The fertilized egg develops into the embryo of the seed which, **upon germination, becomes the mature sporophyte or sexless phase** of the life history with its characteristic number of chromosomes.

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CHAPTER XVII

THE COELENTERATA

THE **Coelenterata** (Gr. **koilos**=hollow+**enteron**=intestine) are all **aquatic** (mostly **marine**) animals, possessing a **single system of internal chambers**, called a **gastro-vascular-cavity.** This cavity has a single opening which serves both as a mouth and a vent for egestion and excretion. In other words, **digestion and circulation all occur in this single tubular cavity.** In all the higher forms of animal life there is a **coelom** ( ), that is, a **cavity between the intestinal tract and the body wall.** This was observed in the frog where all the **viscera** ( ) are **inside the body** but **outside the intestinal tract.**

In the **Coelenterata,** there is a **radial symmetry** as contradistinguished from the **bilateral** symmetry of the frog.

The animals belonging to this phylum are **diploblastic,** that is, they have gone through the gastrula stage in developing and remained stationary at the end of that stage, with this exception, that they just **begin** forming a **third layer** which, however, **never becomes a regular tissue.** The **entoderm** and **ectoderm** are separated from each other by a thick mucilaginous **mesoglea** ( ) or **mesenchyme** ( ). The point of value here is that, in the higher forms, this **midlayer becomes an actual tissue** by forming a very definite sheet of cells, called the **mesoderm,** while in the **Coelenterata** the layer does **not become cellular.** The midlayer here acts as though it were **about to form into a tripoblastic animal, but has not succeeded.**

A few **migratory cells** may be found in the mesoglea, but as a whole it is **non-cellular.**

The phylum is further distinguished by the fact that, in practically all its members, there are **stinging cells** [sometimes called **nettle-cells** or **nematocysts** ( )].

Nerve cells (sensory) and **muscle cells** both **occur.**

Reproduction by non-sexual methods is the more common, though sexual methods **may alternate** with non-sexual to form individuals of quite unlike appearance.

HYDRA FUSCA

The classic coelenterate for laboratory study is this little animal (Fig. 152), found in ponds and streams attached by its **basal end** to various types of aquatic vegetation. It is from 2 to 20 mm. long; consequently it can be seen by the naked eye.

The entoderm contains the **brown bodies** from which the animal receives its name. The animal itself has a **mouth** opposite the basal disk.

About the mouth, there is a varying number of **tentacles,** usually four to seven. These are closed at their free ends, but their interior channels are a direct continuation of the gastro-vascular cavity.

At the **distal third** of the body, the **male gonads,** the **testes,** are seen as **cone-shaped elevations** during the breeding season (September and October), while the **female gonads,** the **ovaries,** are **knoblike projections** close to the basal disk. In addition to these sexual organs, one may find **buds** on various parts of the body.

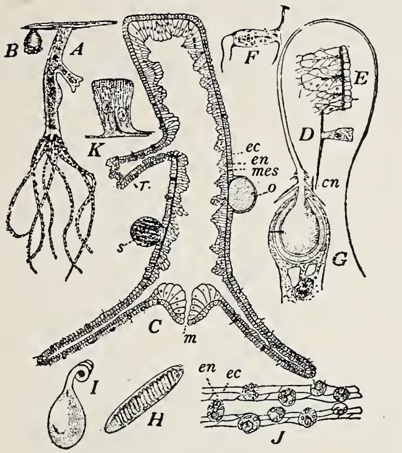


Fig. 152. *Hydra.*

A, an animal in its expanded form; *B,* the same animal contracted; *C,* a diagram of the longitudinal section of the animal, showing the internal structure; *D,* an epithelio-muscle cell; *E,* a bit of the body wall highly magnified showing the two layers of the body; *F,* a digestive cell; *G,* one of the nematocysts with its thread extruded; *H,* a second type of nematocyst with the coiled thread within the sac; *I,* nematocyst of the third type with its thread extruded; *J,* a bit of the tentacle, very highly magnified, showing the batteries of the nematocysts; *K,* two of the secreting cells of the basal disk. *cn,* cnidocil; *ec,* ectoderm; *en,* endoderm; *m,* mouth; *mes,* mesogloea; *o,* ovary; *s,* spermary; *t,* new tentacle forming. (After Conn.)

The H y d r a is a **diploblastic animal,** that is, one which has remained in the **gastrula stage.** This means that the simple **indentation** of the original blastula has given the a n i m a l only **epithelial** tissue, for epithelium is **surface** tissue, and both inner and outer portions of this animal are surface tissues.

The **ectoderm** is primarily **protective** and **sensory,** and is made up of two principal kinds of cells: (1) **epitheliomuscular,** and (2) **interstitial.** The former are shaped like inverted cones, and possess long (up to .38 mm.), unstriped **contractile fibrils** at their inner ends. These enable the animal to expand and contract.

The **interstitial cells** lie among the bases of the epitheliomuscular cells. They give rise to three kinds of **nematocysts** or stinging cells (Fig. 153). Nematocysts are present on all parts of the body, **except the basal disc,** and are most numerous on the tentacles. The interstitial cell, in which the nematocyst develops, is called a **cnidoblast** ( ). It contains a **nucleus** and develops a trigger-like process, the **cnidocil** ( ), at its outer end, but is almost completely filled by the pear-shaped nematocyst. Within this structure is an inverted, coiled, thread-like tube with barbs at the base. When the nematocyst explodes, this tube turns rapidly inside out and is able to penetrate the tissues of other animals. The explosion is probably due to internal pressure produced by osmosis, and may be brought about by various methods such as the application of a little acetic acid or methyl green. Many animals when "shot" by nematocysts are immediately paralyzed and sometimes killed by a poison called hypnotoxin which is spread by the tube.

Two kinds of nematocysts, smaller than those just described, are also found in the ectoderm of **Hydra**. One of these is cylindrical and contains a barbless thread which, when discharged, aids in the capture of prey by coiling around the spines or other structures that may be present.

Certain ectoderm cells of the basal disk of **Hydra** are **glandular** and secrete a sticky substance for the attachment of the animal.

The **entoderm**, the inner layer of cells, is primarily **digestive, absorptive**, and **secretory**. The digestive cells are large, with muscle fibrils at their base, and flagella, or pseudopodia, at the end which projects into the gastrovascular cavity. The flagella create currents in the gastrovascular fluid, and the pseudopodia capture solid food particles. The glandular cells are small and without muscle fibrils. Interstitial cells are found lying at the base of the other entoderm cells.

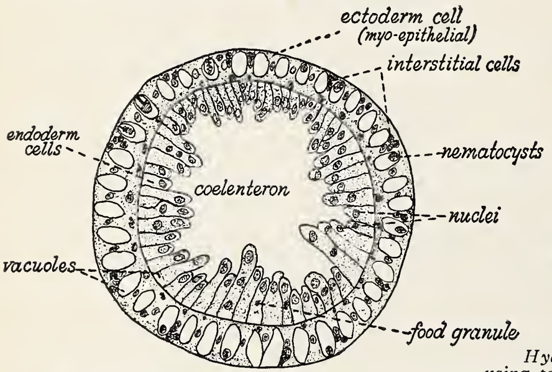


Fig. 153. Transverse Section of *Hydra fusca.* (After Shipley and MacBride.)

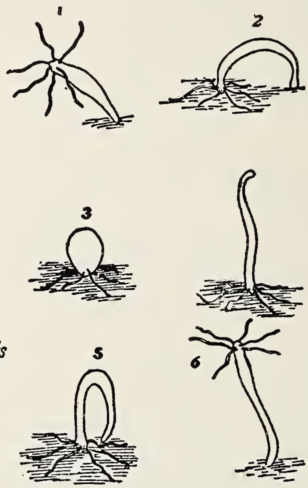


Fig. 154.

Hydra moving like a measuring worm and using tentacles as feet. (From Jennings, after Wagner.)

The **mesoglea** is an extremely thin layer of jelly-like substance situated between the other two layers.

From recent investigations it seems well established that **Hydra** possesses a **nervous system**, though complicated staining methods are necessary to make it visible. In the ectoderm there is a sort of plexus of nerve-cells connected by nerve-fibers with centers in the region of the mouth and foot. Sensory cells in the surface layer of cells serve as external organs of stimulation, and are in direct continuity with fibers from the nerve cells. Some of the nerve-cells send processes to the muscle fibers of the epitheliomuscular cells, and are, therefore, motor in function. No processes from the nerve-cells to the nematocysts have yet been discovered, though they probably occur. The entoderm of the body also contains nerve-cells, but not so many as are present in the ectoderm.

Hydra obtains its food by throwing out **nematocysts** and paralyzing its prey. The surface of the tentacle itself is somewhat sticky, which assists in keeping food from getting away, once the tentacle bends about it and carries it to the animal's mouth. After the food enters the mouth, the forepart of the animal contracts to send it downward.

There are **gland-cells** in the **entoderm** which secrete a digestive fluid, and it is probable that some digestion takes place in the entoderm cells themselves. These latter have little flagella by which food is whipped about. When digestion takes place within these entoderm cells, digestion is said to be **intracellular.**

It is interesting to note that **Hydra** will not respond to food stimuli or capture prey after being fed.

The normal position of **Hydra** is an attachment to some solid object by its basal disk. When the animal moves from one attached place to another, it uses its tentacles as feet, slowly moving them along as though walking upon them, and when a suitable location has been found, releasing its body at the basal end and attaching it to the newly-found spot. (Fig. 154.)

The reproduction of **Hydra** is especially interesting in that it furnishes us with excellent proof for Weismann's insistence on the **separation** of **somato-plasm** and **germ-plasm.**

This animal usually reproduces by budding, as does yeast, except that the bud in this instance pushes out and becomes **stalk-shaped.** The tentacles of the bud grow from the distal end of the new stalk bud, and the entire new organism is pinched off from the mother stalk or body. (Fig. 152, C.)

In fact, it is not uncommon for one of these buds to form new buds on its body before it is ready for independent existence itself. At all times, the cavity of the newly forming animal is in **direct continuation** with the mother cavity, until the pinching-off process occurs.

There is a division of the body sometimes, though very infrequently, by **simple fission** ( ), that is, by a splitting of the entire animal **lengthwise,** commencing from the distal end and extending to the basal disk. Sometimes, also, even the buds reproduce in this manner, while transverse fission is not unknown.

In the **sexual method,** the spermatozoa from the testes escape into the surrounding water. The **eggs arise** in the ovary **from ectodermal interstitial cells.** Usually only one egg in the ovary grows to maturity, though several may begin growth, only to have one of them—**the stronger by virtue of position, or ability to obtain more food**—absorbing the others. Two **polar bodies** are given off from this egg when it is ready for fertilization, and then it is said to be **mature.**

The **cleavage** of the egg **is total,** and **almost equal.** After this original egg has divided several times, the blastula is formed with a cavity called the **blastocoel** ( ). Cells from the inner portion **bud off** and make a sort of **solid gastrula-like structure**; this later becomes the **entoderm.** The ectoderm then **secretes a thick chitinous** ( ) **shell** covered with sharp projections, after which the embryo separates from its parent and falls to the bottom of the disk in which it is placed. Here it remains unchanged for several weeks. **Interstitial cells** then make their appearance followed by another resting period, after which the outer chitinous envelope breaks away and the elongation of the escaped **embryo** continues. **Mesoglea** is now secreted by the ectoderm and entoderm cells. A circlet of tentacles arises at one end, and a mouth appears in their midst. The young **Hydra** thus formed soon grows into the adult condition. Almost any part of the **Hydra** may be cut off, and **each part will grow into a complete new animal.** This is supposed to be due to the fact that **Hydra** is an animal composed of **tissues** which have **not yet become organs** as in the higher animals. Therefore, **the original germ-cells have not divided so often** as in higher animals, and **each cell contains a little portion of germ-plasm** which causes each cell to have **the power or potentiality of producing a complete organism.** This theory receives additional weight from the fact that the **Hydra can** and **does reproduce in practically every known way: sexual, asexual,** by **budding,** by **longitudinal** and **transverse fission,** in addition to having the ability of restoring any lost part, and of forming a complete new animal from the smallest part.

When, however, an animal is classified in one of the higher phyla and its somatoplasm is, therefore, further removed from the germplasm, the regenerative ability decreases. This is shown in man, where a piece of skin, when removed, will be replaced, though an entire finger will not.

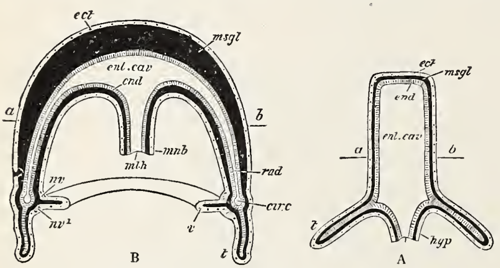


Fig. 155. Medusa, showing gastrula-form.

Diagrams showing the similarities of a polyp *(A)* and a medusa *(B)*. *circ,* circular canal; *ect,* ectoderm; *end,* entoderm; *ent. cav,* gastrovascular cavity; *hyp,* hypostome; *mnb,* manubrium; *msgl,* mesoglea; *mth,* mouth; *nv,* nerve rings; *rad,* radial canal; *v,* velum. (From Parker and Haswell.)

Regeneration means that a part of an organism can reproduce the whole or at least a portion of the lost part. Regeneration is to be distinguished from **reproduction,** though in **Hydra** the two are intimately related.

As has been stated, there is an **alternation of generations in Hydra.** The **form** we have been discussing so far, is called the **Hydroid form or the polyp** ( ), while the **asexual** form, so different in appearance from the hydroid, **is umbrella shaped** and is called a **medusa** ( ) (Fig. 155). The convex portion is usually the upper surface. Tentacles hang down from the edges. At first glance the two forms appear totally dissimilar, but with a clear conception of what a gastrula really is, we can readily imagine grasping the hydroid form by the mouth and pushing this portion of the animal in upon itself, when we have the **gastrula** still, and **also** the **medusoid form.**

It must be remembered that some species may **always** retain the medusoid form and others the hydroid, while still a third may **alternate regularly or irregularly** between the two.

OBELIA ( )

This is a **colonial** form of **Hydra** found attached to rocks, wharves, and to various algae. New individuals form by budding, but the newly-formed animals remained attached to the parent stalks. (Fig. 156.)

Such a colony consists of a basal stem, the **hydrorhiza** ( ), which is attached to the substratum. At intervals, upright branches, known as **hydrocauli** ( ), are given off. At every bend in the hydrocaulus, a branch arises. The stem of this side-branch

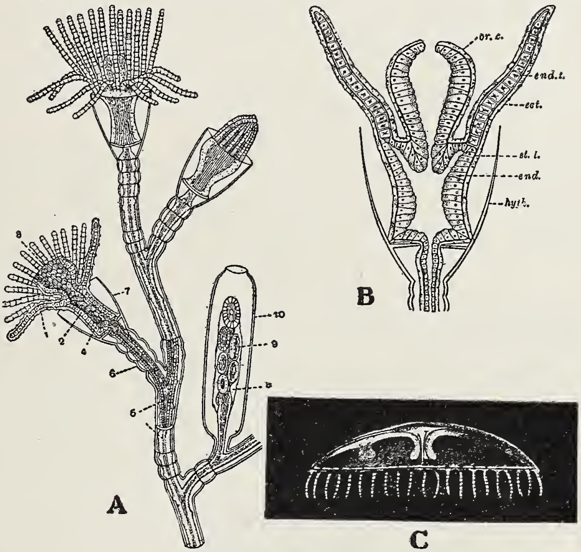


Fig. 156. *Hydrozoa.*

A, part of a colonial Hydrozoan, *Obelia.* *B,* Longitudinal section through a single hydranth. *C,* Cross section through medusoid individual. 1, ectoderm; 2, entoderm; 3, mouth; 4, coelenteron; 5, coenosarc; 6, perisarc; 7, hydrotheca; 8, blastostyle; 9, medusa-bud; 10, gonotheca; *or.c,* mouth region; *end.* and *endt.,* entoderm; *ect.,* ectoderm; *st.l.,* mesoglea lying between ectoderm and entoderm; *hyth,* hydrotheca. (From Borradaile after various authors.)

is ringed and expanded at the end into a hydra-like structure, the **hydranth** ( ). Each **individual polyp** consists of a hydranth and the part of the stalk between the hydranth and the point of origin of the preceding branch. Full-grown colonies usually bear reproductive members **(gonangia)** in the angles where the hydranths arise from the hydrocaulus.

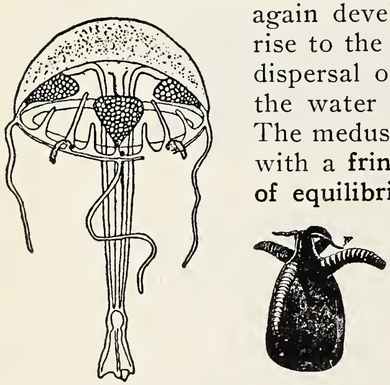
All of the soft parts of the **Obelia** colony are protected by a chitinous covering, called the **perisarc** ( ), which is ringed at various places, and expanded into **gonothecae** and cup-shaped **hydrothecae** ( ) to accommodate the hydranths.

A shell extends across the base of the hydrothecae which serves to support the hydranth. The soft parts of the hydrocaulus and of the stalks of the hydranths constitute the **coenosarc** ( ) and are attached to the perisarc by minute projections. The coenosarcal cavities of the hydrocaulus open into those of the branches and thence into the hydranths, producing in this way a common **gastro-vascular cavity.**

The coenosarc consists of two layers of cells—an outer layer, the **ectoderm,** and an inner layer, the **entoderm.** These layers are continued into the hydranth. The **mouth** is situated in the center of the large knob-like **hypostome** ( ) and the **tentacles** ( ), about thirty in number, are arranged around the base of the hypostome in a single circle. Each tentacle is solid and consists of an outer layer of ectodermal cells and a single axial row of entodermal cells with a large number of **nematocysts** at the extremity. The hydranth captures, ingests, and digests food just as does **Hydra.**

The **reproductive organs** develop quite like the hydranths, as buds from the hydrocaulus. They thus represent modified hydranths. The central axis of each is called a **blastostyle** ( ), and, together with the gonothecal covering, is known as the **gonangium** ( ). The blastostyle gives rise to **medusa-buds** which soon become detached and pass out of the gonotheca through the opening in the distal end.

Some **medusae** produce eggs, and others, sperm. The fertilized eggs again develop into colonies like those which gave rise to the medusae. The medusae provide for the dispersal of the species, since they swim about in the water and establish colonies in new habitats. The medusae of **Obelia** are shaped like an umbrella with a **fringe of tentacles** and a number of **organs of equilibrium** on the edge. Hanging down from the center is the **manubrium** ( ) with the mouth at the end. The gastro-vascular cavity extends out from the cavity of the manubrium into four **radial canals** on which are situated the reproductive organs.



A. B.

Fig. 157.

A. Liriope Exigua (family *Geryoniidae*). (Mayer.)

B. Hydralike stage in the development of *Gonionemus.* One of the tentacles is carrying a worm *(w)* to the mouth. Tentacles in contracted state. (From the Cambridge Natural History, after Perkins.)

The **germ-cells** of the medusae of **Obelia,** after arising in the ectoderm of the manubrium, migrate along the radial canals to the reproductive organs. When mature, they break out into the water. The eggs are **fertilized** by spermatozoa which have escaped from other medusae. Cleavage is similar to that of **Hydra**, and a hollow **blastula** and solid **gastrula-like** structure are formed. The gastrula-like structure soon becomes ciliated and elongates into a free-swimming larva called a **planula** ( ) which soon acquires a central cavity and becomes fixed to some object. This then forms a new colony.

When there is an alternation of generations, one sexual, reproducing by eggs and spermatozoa, and the other asexual, reproducing by division or budding, such an alternation of generations is called **metagenesis** ( ).

In **Obelia** the asexual generation (the colony of polyps) forms buds of two kinds, the **hydranths** and the **gonangia** ( ). The sexual generation (the medusoid) reproduces only by eggs and spermatozoa.

Hydra have no regular medusoid stage, and **Geryonia** (Fig. 157A), ( ), no polyp, or hydroid, stage.

Gonionemus (Fig. 157B) ( )

The structure of a medusa, or hydrozoan jellyfish, is well illustrated by **Gonionemus,** which is quite common along the eastern coast of the United States. It is about half an inch in diameter. In general form it is similar to the medusa of **Obelia.** The convex or **aboral** surface is called the **exumbrella** ( ), and the concave, or oral surface, the **subumbrella** ( ). The subumbrella is partly closed by a perforated membrane called the **velum** ( ). The animal takes water into the subumbrella-cavity, and then forces it out through the central opening in the velum by contracting its body, thus propelling itself in the opposite direction. This method of locomotion is called **hydraulic.** It is common to all medusae.

The **tentacles** (from sixteen to about eighty in number) are capable of great contraction. Adhesive or **suctorial pads** are found near their tips. Hanging down into the subumbrellar cavity is the **manubrium** with the mouth at its end surrounded by four frilled oral lobes. The mouth opens into a **gastrovascular cavity** which consists of a central "stomach" and four **radial canals.** The radial canals enter a **circumferential canal** which lies near the margin of the umbrella.

The cellular structure of **Gonionemus** is similar to that of **Hydra,** but the mesoglea is thicker and gives the animal a jelly-like consistency. Then there are many nerve cells scattered about beneath the ectoderm, and a nerve ring is placed about the velum. There are **sensory cells** with a **tactile function** on the tentacles. At the margin of the umbrella there are two kinds of sense organs: (1) Those at the base of the tentacles are round bodies containing pigmented entoderm cells and communicate with the circumferential canal. (2) Those between the bases of the tentacles are small outgrowths, probably organs of equilibrium, that is, **statocysts** ( ). **Muscle fibers** are present in both exumbrella and subumbrella.

Beneath the radial canals the sinuously folded **reproductive organs, or gonads,** are suspended. **Gonionemus is dioecious** ( ), each individual producing either eggs or spermatozoa. These reproductive cells break out directly into the water, where **fertilization** takes place. A ciliated **planula** develops from the egg as in **Obelia.** This soon becomes fixed to some object and a mouth appears at the unattached end. Then four tentacles grow out around the mouth, and the **hydra-like larva** is able to feed. Other similar **hydra-like larvae** bud from its walls. How the medusae arise from these larvae is not known, but probably there is a direct change from the hydroid form to the medusa.

POLYMORPHISM

Whenever there is a division of labor among the different members of the same colony so that each does a particular work, such colony is said to be **polymorphic** ( ) if there are more than two kinds of specialized individuals; **dimorphic,** if only two different specializations have taken place.

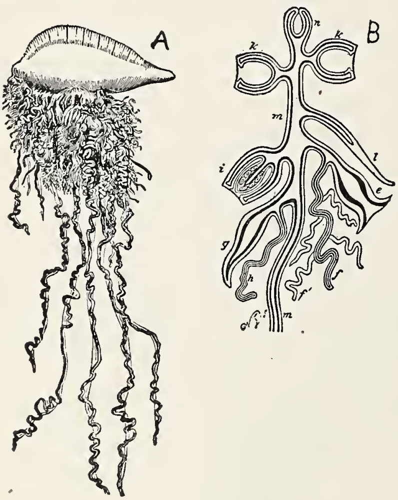


Fig. 158.

A, Physalia or Portuguese man-of-war, a colonial *Hydrozoon.* (From Hegner, after Agassiz.)

B, Diagram showing possible modifications of medusoids and hydroids of a hydrozoan colony of the order *Siphonophora. c.* gastrozooid with branched, grappling tentacle, *f; g,* dactylozooid with attached tentacle, *h; i,* generative medusoid; *k,* nectophores (swimming bells); *l,* hydrophyllium (covering piece); *m,* stem of corm; *n,* pneumatophore. The thick black line represents entoderm, the thinner line ectoderm. (From Hegner after Allman.)

The **"Portuguese man-of-war"** (Fig. 158) is an excellent example of the former, in that it is a bladder-like structure to which many tentacles are attached. It floats upon the water. Some of these tentacles are **nutritive,** others are **tactile** ( ), some contain **batteries of nematocysts,** others are **male reproductive zoöids,** and still others give rise to **egg-producing medusae.**

The **Coelenterata** (together with the **Echinoderma)** were formerly called **Radiata** on account of their radial form. It is now known that in the higher groups of coelenterates, this radial form may be transformed into a biradial or bilateral symmetry.

Older writers often spoke of the coelenterates as **Zoöphyta** (animal-plants) on account of their resemblance to plants both in appearance and in their method of attachment. Then, too, these animals simulate

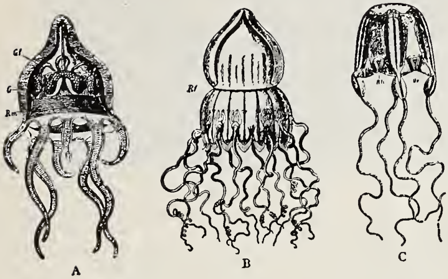


Fig. 159. *Scyphozoa.*

A, Tessera princeps, order Stauromedusae. *B, Periphylla hyacinthia,* order Peromedusae. *C, Charybdea marsupialis,* order Cubomedusae. *G,* gonads; *Gf,* gastral filaments; *ov,* gonads; *Rf,* annular groove; *Rk,* marginal bodies; *Rm,* circular muscle; *T,* tentacles. (From Sedgwick, after Haeckel.)

Fig. 160. Examples of *Alcyonoria.*

Coral. *A, Tubipora musica,* organ-pipe coral, a young colony. *Hp,* connecting horizontal platforms; *p,* skeletal tubes of the zooids; *St,* the basal stolon. *B, Alcyonium digitatum,* with some zooids expanded. *C, Corallium,* a branch of precious coral. *P,* polyp. *D, Pennatula sulcata,* a sea-feather. (A and B, from Cambridge Natural History; C, from Sedgwick, after Lacaze Duthiers; D, from Sedgwick, after Kolliker.)

plant-conditions by their method of reproduction, namely, by fission and budding, as well as by forming colonies.

CLASSIFICATION

There are three great classes of coelenterates — **Hydrozoa** ( ), **Scyphozoa** ( ), and **Anthozoa** ( ).

The **Hydrozoa** possess neither stomodaeum nor mesenteries ( ), and their sex-cells are discharged directly to the exterior. **Hydra** and **Obelia** belong to this class.

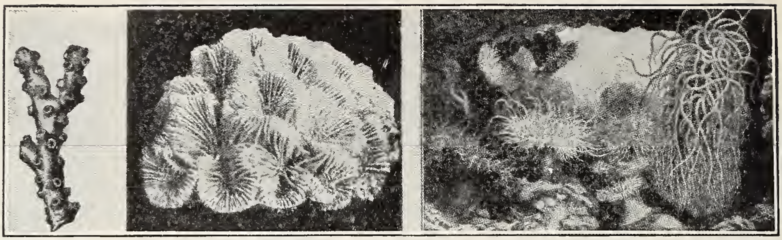
The **Scyphozoa** may, or may not, possess a stomodaeum and mesenteries. The stomodaeum is more or less equivalent to the gullet in coelenterates, serving as the passageway between mouth and the gastrovascular cavity or "stomach." The membranes, which hold this stomodaeum in place, are called **mesenteries.**

The position of tentacles and tentaculocysts is made use of in separating the coelenterates into the various classes.

Examples of Scyphozoa (Fig. 159) are: **Tessera,** order **Stauromedusae; Periphylla,** order **Peromedusae;** and **Charybdea,** order **Cubomedusae.**

The **Anthozoa** are divided into two sub-classes as follows:

Sub-class I. Alcyonaria (Fig. 160), all of which have eight hollow, pinnate, tentacles and eight complete mesenteries. They also possess one **siphonoglyphe,** which is ventral in position, while all the retractor muscles of the mesenteries lie on the side toward the siphonoglyphe ( ).



A. B. C.

Fig. 161. Examples of *Zoantharia*.

A, Oculina speciosa, a branch of madreporarian coral. (After Sedgwick.)
B, Meandrina, a rose-coral of the order Madreporaria. (After Weysse.)
C, A group of sea anemones. (After Andres.)

Examples of **Alcyonaria** are the organ-pipe coral, known as **Tubipora,** of the order **Stolonifera,** and the pretty sea-fans and the red coral used in jewelry. The latter is known as **Corallium** of the order Gorgonacea.

Sub-class II. Zoantharia (Fig. 161). These usually possess many simple, hollow tentacles, generally arranged in multiples of five or six. There are two siphonoglyphes as a rule, and the mesenteries vary in number. The retractor muscles are never arranged as in the **Alcyonaria.** A skeleton may or may not be present. The animals may be simple or colonial.

Examples of **Zoantharia** are the sea-anemones such as **Actiniaria,** and the stony corals such as **Oculina** of the order **Madreporaria,** and the rose-coral **Meandrina,** order **Madreporaria.**

CHAPTER XVIII

INTRODUCTION TO THE COELOMATA

FROM what has already been learned, it is known that animals may be divided, according to whether or not they have a backbone, into great groups—the **vertebrates** and the **invertebrates**. Also, division may be made according to whether they are composed of one or more cells into **protozoa** and **metazoa**. The latter division may again be subdivided according to the number of germ layers each form develops, into **diploblastic** and **triploblastic** organisms.

Now we come to another common method of classifying animals into two groups—the **coelomata** and the **acoelomata.**

With the exception of the frog, all animals studied so far—the Protozoa and Coelenterata—belong to the **acoelomata,** because they have no additional cavity between the digestive tract and the body wall. **Coelomata have such a body-cavity.** All animals higher in the scale of life than hydra are coelomates.

It will be remembered that in hydra there was a thick mucilaginous substance—the mesoglea—formed between the ectoderm and entoderm. In some of the lower forms of acoelomata there are processes stretching across from inner to outer germ-layer, which often secrete fibers which become connective tissue or even muscular fibers. Where the cells and fibers are sparse the space is called a **primary body-cavity.** Where they are abundant, there is a tissue called **parenchyma** ( ) or **connective tissue.**

This body cavity, also known as the **coelomic cavity** (Fig. 162) or **coelom** (Gr. **koiloma**=a thing hollowed out), consists of one or more pairs of sacs with perfectly defined walls lying at the sides of the entodermic tube. In the adult these sacs join above and below the entoderm, while the adjacent walls entirely or partly break down to form one continuous cavity. The **wall of the coelom** and **the tissues derived from it are mesoderm.**

The distinctive difference between the primary body cavity of the coelenterates and this secondary body-cavity of the coelomates, is a **difference in the walls** of the cavities and **not in the space** between the walls. The outer wall of the primary body cavity is merely ectoderm.

It will be remembered that this primary body-cavity serves both as a digestive and circulatory system in the coelenterates. In the higher animals, therefore, it may be said that the blood-vessels are really part of the primary body-cavity.

In triploblastic animals the **mesoderm** does not form a completely solid mass extending the entire length of the body. A slight cavity is left in its center along the long axis of the organism.

This mesoderm forms in two ways: either (1) by little pouches growing from the entoderm which are then nipped off, or (2) by two large cells which grow as buds from the entoderm, and which, when once formed, grow rapidly, forming the so-called **mesodermic bands.** These bands later become hollowed out. The two cells which form the original bud, are termed **pole-cells.** **This hollowed out portion is the coelom.** A close study of Figure 163 will make a better understanding of the above possible.

It must be understood that both these methods of mesoderm formation are not likely to be found in any one animal.

The open space thus formed, which we have called the coelom, has thus a **layer toward the outside of the body** and a layer of cells, or **wall, toward the entoderm** from which it sprang. The outer wall of the coelom is called the **somatic layer** or the **somatopleure** ( ), while the inner is known as the **splanchnopleure** ( ).

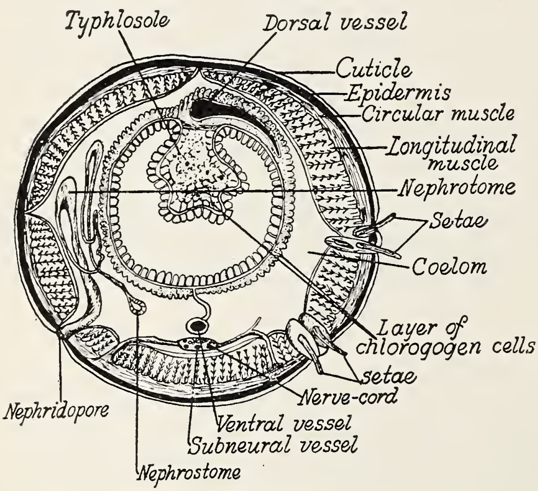


Fig. 162.

Transverse section through the middle region of the body of the earthworm, *Lumbricus*. (From Parker and Haswell, after Marshall and Hurst.)

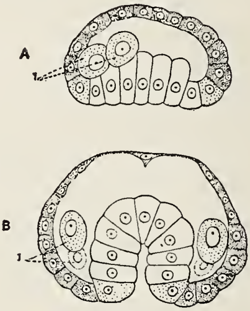


Fig. 163.

Two stages in the early development of a common fresh-water mollusc, *Planorbis*, to show the origin of the mesoderm cells.

The ectoderm cells are deeply shaded, the endoderm cells are unshaded. *A*. Young stage in which the endoderm has not begun to be invaginated; it is a lateral optical section. *B*. Older stage, optical section seen in front view; the endoderm cells are invaginating, and the two mesoderm cells are seen on each side. 1. Mesoderm or pole-cells; in B, each has budded off another mesoderm cell. (After Rabl.)

When pole-cells form, the cavity of the digestive canal is small in proportion to the thickness of its wall, so that the pole-cell may be considered as "a solid pouch."

In most Coelomata the mesoderm, or coelomic wall, forms by far the greater portion of the body. There are sometimes cells which form in the primary body-cavity, to which some writers have also applied the term mesoderm. **This term should, however, be reserved for the walls of the coelom as just described, while mesenchyme** ( ) should be used for the cells forming within the primary body-cavity.

Mesenchyme arises from different germ-layers in different phyla of animals. It may arise from the entoderm or ectoderm or both, or even from the walls of the coelom. In this latter case it may spring from ectoderm, entoderm, and mesoderm. In the higher Coelomata it arises, however, partly from the ectoderm but chiefly from the outer wall of the coelom. **Everywhere it gives rise to connective tissue** and to the tissues developed from this (tendon, cartilage, bone, etc.), whereas the **coelomic wall,** or **true mesoderm, gives rise to the generative cells and their ducts, and the main parts of the muscular system,** including the muscular coats of the principal blood-vessels.

The **entoderm,** after the mesoderm has separated from it, **forms the lining of the digestive tube and of its appendages,** which in the higher vertebrata are such organs as the **lungs, liver, pancreas,** and **urinary bladder.** The basis of the skeleton of vertebrata, the gelatinous rod called the **notochord, also arises from the entoderm.**

After gastrulation has taken place in the growing embryo, there are only two germ layers, ectoderm and entoderm. The inner layer undergoes various changes, as it is to be used for a totally different purpose from its outer, protective layer. It must be remembered, however, that just after indentation, both layers are alike in that they have both constituted the simple blastula. The blastula, it will be remembered, is but a single layer of cells forming a more or less spherical body. The opening formed by gastrulation, and known as the mouth or **stomodeum** ( ), does not undergo the same change that does the part on the more interior portion of what is now called the entoderm. In fact, the **mouth region remains ectodermal.** As soon as an organism has formed three germ-layers and has both an opening in its body for ingestion as well as egestion of food, there comes another infolding of ectoderm in the gastrula at the opposite end from the stomodeum. This forms an anal opening which is called a **proctodeum** ( ). This infolding, just as the stomodeal infolding, is also ectoderm.

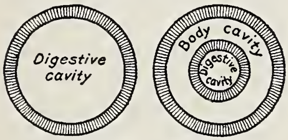


Fig. 164.

Diagrammatic cross section of the body of a coelenterate (such as the hydra) and of a coelomate. The latter forms a tube within a tube.

It is of interest and value here to know that the **entire brain and nervous system arise from ectoderm.** It will be readily understood why this is so, when it is realized that no organism from the simplest flower up to man, could possibly live unless there were some method by which such organism could protect itself when danger threatened. Any mechanical injury, such as pressure or laceration, cannot affect the body unless it strikes the outer portions first. Therefore, the **sensory nerve endings must be placed close to the outer portion** of the body so that they can receive the message of threatened danger first. These danger messages are then carried to the **central nervous** system where a **coördination** must be brought about between the sensory fibers and the motor nerves, thus making it possible for any or all parts of the body to be withdrawn from the zone of danger.

For **toxic injuries,** as well as **parasitical invasions,** which come through the intestinal tract, the student must think of the body, when drawn out completely, as forming a tube within a tube. (Fig. 164.)

The inner one, called the intestinal, or digestive tract, has an opening straight through the body. This means that the inside of the digestive tract is really **outside the body in so far as** exterior environmental conditions may affect it, such as temperature, air, etc. In other words, it is as though one took an ordinary small gas or water pipe and placed it in water. There would be the same kind and quality of water on the inside as there would be on the outside of the pipe.

The larger outer tube is the outer body wall.

As the internal anatomy of the lower animals was first studied by physicians and others primarily interested in human anatomy, a large number of names is used in the description of simpler animals which are based on fanciful resemblances between their organs and those of man. Many of these names are, therefore, quite misleading. For example: The word stomach in the lobster denotes part of the stomodeum, while in the vertebrates it signifies part of the entodermic tube. The pharynx ( ) of an earthworm is the stomodeum, while in fishes it includes both stomodeum and the first part of the entodermic tube.

Names taken from the higher animals, which are customarily used in the description of the alimentary canal, are as follows: Mouth or **buccal-cavity, pharynx, oesophagus, stomach** or **crop, gizzard, intestine,** and **rectum.** These names apply to parts succeeding one another in the order above given. Many biologists hold that it would perhaps be more logical to sweep away altogether these and a host of similar terms employed to designate other parts of the body, but as these terms have become so deeply engrained in zoölogical literature such a course would render unintelligible most of the anatomical descriptions of species we possess.

CHAPTER XIX

THE EARTHWORM

EARTHWORMS are found in practically all parts of the country, living in burrows not lower than 12 to 18 inches beneath the earth's surface. It is in about these depths that they find the richest portions of decaying vegetable and animal substances upon which they feed. Professor Latter has given us a most interesting account of these animals. During "periods of prolonged drought or frost they descend to greater depths and undergo **aestivation** ( ) or **hibernation** ( ), as the case may be, coiled up into a compact spiral and lying in a small excavated chamber. This is lined with small stones which prevent close contact with the surrounding earth and so permit free respiration. The sides of the burrow are kept moist by slime discharged from the glandular cells of the skin, and perhaps by liquid discharged from the body-cavity through the dorsal pores which occur in the grooves that separate segment from segment. The slime is said to possess antiseptic properties, and thus preserve the skin of the worm from harmful bacteria.

"The mouth of the burrow is guarded by small stones or more frequently by one or more leaves pulled in to a greater or less distance. Fir-needles, stalks of horse-chestnut leaves and other similar things are often to be seen standing nearly erect upon the ground, their lower ends having been forcibly dragged into the mouth of a burrow by a worm. On still, warm nights in early autumn the rustling noise of fallen leaves being dragged along by worms is often plainly audible in favorable localities. Darwin has pointed out that worms exhibit considerable intelligence in drawing the narrow end of leaves of various shapes foremost into the burrow: the leaves with broad bases and narrow apices are generally pulled in tip first, whereas when the base is narrower than the apex the reverse position is usually found. There is no doubt that worms can judge which end of any leaf is the better to seize. The reason for thus pulling objects into the entrance of the burrow is probably to prevent the entry of foes, centipedes, parasitic flies, etc., to keep the burrow moist by preventing evaporation, to keep out the cold lower strata of air at night, to bring food supplies within safe reach, and also to enable the worms to lie near the mouth of the burrow unobserved. Here, however, they are not secure from all attack, for the quick ears of the thrush and other birds enable them to detect the slightest movement and, with a quick plunge of the beak, to seize, and after a brief tug-of-war, to extract the worm from its refuge. Frequently the well-known worm-castings are thrown up on the surface, and when this is so, leaves are not, as a rule, drawn into the burrows, the heap of castings serving the purpose.

"The burrow is made partly by the awl-like, tapering anterior end pushing aside the earth on all sides, and partly by the actual swallowing of the earth as the worm advances, so that the animal literally eats its way into the soil. The organic material in the swallowed soil serves as food, and the residue in a state of very fine division passes out at the anus, and is used either to form the above mentioned castings or as a lining to the burrow, especially where this passes through hard, coarse earth.

"Perfectly healthy worms seldom leave their burrows completely except perhaps after a very heavy rain. The majority of those so frequently found traveling over the surface of roads and paths after rain are infected by the larvae of parasitic flies and doomed to die. On warm, moist evenings, however, worms may be seen in hundreds lying stretched on the surface of the ground with only the broad flattened posterior end remaining in the burrow. Here we see one of the uses of this modification in the shape of the hinder segments of the body: their greater width enables them to obtain a firm purchase on both sides of the burrow, and thus the worm is provided with a sure anchor on which it can pull, and at the slightest alarm, shoot back like stretched elastic into the security of its burrow. At other times the flat tail is employed trowelwise in smoothing the excrement against the walls of the burrow or in disposing the castings on this side and on that of the mouth of the burrow.

"The effects produced on the surface soil by the action of earthworms have been fully pointed out by Charles Darwin in his well-known book, 'Vegetable Mould and Earthworms.' It will be sufficient here to call attention to a few facts only. Worms play a most important part in maintaining the soil in a state suitable to vegetation. The burrows form ventilating tubes whereby the soil is aerated and respiration by the roots of plants rendered possible; at the same time they open up drainage channels, preventing the surface from becoming waterlogged. Doubtless also roots find an easy passage through the soil along the lines of burrows even after the walls have more or less fallen in. Moreover, the excrementitious earth with which the burrows are lined is peculiarly suited to root fibers, being moist, loose and fertile. Microscopic examination of the earth deposited by worms shows it to resemble two-year-old leaf mould such as gardeners use for seed-pans and pricking-out young seedlings; most of the plant-cells are destroyed, shreds and fragments alone remaining, discolored and friable, mingled with sand grains and brown organic particles. In chemical composition, too, worm-castings are very similar to fertile **humus**.

"The castings which are thrown up on the surface materially improve the quality of the upper soil, and render it more fit for the germination of seeds, many of which directly or indirectly get covered by the upturned earth. It has been reckoned that there are upwards of 50,000 worms in an acre of soil of average quality: hence the total effect of the work of this vast host must be very considerable. Each worm ejects annually about 20 ounces of earth. The weights of earth thrown up in a single year on two separate square yards observed by Darwin were respectively 6.75 and 8.387 pounds, amounts which represent respectively 14.58 tons and 18.12 tons per acre per annum.

"In addition to this tilling action worms improve the quality of the soil by the leaves and other organic **debris** which they drag into their burrows, and thus bring within reach of bacteria. These, as it is well known, especially abound in the upper soil, and effect the speedy decomposition of dead animals and vegetable tissues.

"Archaeologists are indebted to worms for the preservation of many ancient objects, such as coins, implements, ornaments, and even the floors and remains of ancient buildings that have become buried by the soil thrown up as worm-castings. The process of disappearance is, of course, hastened by the excavations effected by the worms below the surface, for the collapse of the burrows slowly but surely allows objects on the surface to sink downward.

"In the disintegration of rocks, and the denudation of the land, worms play an important part. The penetration of the burrows, and the lining with castings, carries down the humus-acids to a considerable depth and exposes the underlying rocks to their solvent action. Within the body of the worm itself small stones and grains of sand are reduced to yet finer dimensions and rendered the more easy to transport by wind and water. On sloping surfaces the upturned castings, at first semi-fluid, flow down, and when dry roll down the incline, or are washed by the rain into the valleys and ultimately carried out to sea, while on level ground the dried castings are blown away to lower spots by the wind. The more or less parallel ridges that are frequently found on the sloping sides of grass-clad hills are in part, at any rate, formed by the material derived from worm-castings, which has temporarily lodged against tufts of grass, etc., and in turn furnishes a richer and deeper soil for stronger growth which arrests yet more and so increases the ledge. All land surfaces, whether level or sloping, provided they are occupied by worms, are reduced in altitude by their action. In no small degree, then, may earthworms be held responsible for our valleys and hills and all the softer features of our scenery."

EXTERNAL APPEARANCE

There are rings or **segments**, formed by constrictions or **annuli** (Fig. 165), extending along the entire length of the animal's body. The segments themselves are known as **somites** or **metameres**. It is from these ring-like (L. **annulus**-ring) constrictions and segments that the animals belonging to this group are named **Annelids** or **Annulata**. Worms are divided into annelids, or segmented worms, **plathyhelminthes** or flat worms—(Gr. **platy**=flat+**helminthes**=worms); and **nemathelminthes** or **thread-worms** (Gr. **nema**=thread+**helminthes**=worms).

The important external characteristic in the annelids is, then, a **regional** differentiation. That is, the forming of separate segments or regions externally, and a separation and segmentation of many internal structures. Metamerism is common in all higher forms of organisms except the soft-bodied animals such as the **Molluscs** and the spiny-skinned **Echinoderms.** In man this metamerism is distinctly shown in the separate segments of the spinal column.

Fig. 165.

Latero-ventral view of *Lumbricus terrestris,* slightly smaller than life-size. (From Hatschek and Cori.)
1. Prostomium. 2. Mouth. 3. Anus. 4. Opening of oviduct. 5. Opening of vas deferens. 6. Genital chaetae. 7. Lateral and ventral pairs of chaetae.
XV, XXXII, and XXXVII are the 15th, 32nd, and 37th segments. The 32nd to the 37th form the clitellum. (After Latter.)

There are many differentiations in various regions of the earthworm's body. For example, the anterior end is sensitive to touch and light to a much greater degree than the middle and posterior portions. On the eighth, ninth, fourteenth, and fifteenth segments there are openings of the reproductive system, while from the twenty-eighth to the thirty-seventh segments a broad band surrounds the dorsal and lateral portions of the worm, called a **clitellum,** the function of which will be explained under reproduction.

There are from 140 to 180 segments in the earthworm. All of the differentiation just mentioned occurs toward the anterior end of the worm. We, therefore, say that the earthworm has an **anterior-posterior differentiation.**

As the earthworm will always place itself in a definite position when crawling along—that is, will "right" itself if it be turned about, we speak of that portion toward the surface on which it moves as the **ventral surface,** and the surface away from this as the **dorsal.** If an animal thus rights itself, there must be a difference between the ventral and dorsal surfaces. This difference is spoken of as a **dorso-ventral differentiation** or **dorsiventrality.**

The ventral surface will be found to be more flattened than the dorsal, while many little whitish glands are present toward the anterior end. On the ventral surface are also found the mouth, anus, reproductive, and excretory openings, as well as peculiar bristle-like **setae.** These latter will be discussed under locomotion.

The earthworm, like the frog, is bilaterally symmetrical. A median dorso-ventral line drawn through the worm divides it into two equal parts. This will be understood better when it is remembered that all unpaired parts of the animal, such as the mouth, anus, central blood vessel, etc., would be cut into two equal parts by a medial section, while all paired portions such as setae and reproductive openings would have one-half of such paired portion on each side of the animal.

The **dorsal excretory pores,** one to each somite posterior to the tenth, lie in the constrictions and are difficult to find, but on the ventral surface various openings can readily be seen. Principally, these are two pairs of minute pores between the ninth and tenth and the tenth and eleventh somites, coming from the **seminal receptacles.** The **male genital openings** are on the fifteenth, and the pair of **female genital openings** are on the fourteenth somites. The **excretory organs,** called **nephridia,** have two openings on each somite behind the first three or four and anterior to the last. Practically all of the ventral openings posterior to the male genital pore, with the exception of the anus, are too small to be seen with the unaided eye.

The animal moves along primarily by alternate rhythmic constrictions of the longitudinal and circular muscles of the body-wall which contract and elongate successive regions of the body. There are eight chitinous **setae** to each somite, easily felt if the animal be drawn between the fingers. An ordinary hand-lens will show them quite clearly. There is then a double way in which the worm moves, the muscular action furnishing the contraction and expansion and the setae furnishing cog-like projections by which the worm can make forward progress. This is well exemplified by the fact that if an earthworm be placed on a highly polished surface, little if any progress is made by it.

Muscles are attached to the inner parts of the setae, making it possible to shift their positions. The flattened tail of **Lumbricus terrestris,** serves as an anchor, while the anterior portion of the animal's body lies on the surface of the earth.

INTERNAL STRUCTURE

The earthworm illustrates a **coelom** (Fig. 162) as well probably as any form which could be given the student, for upon making either dorsal or ventral longitudinal incision the animal will give the appearance of a tube within a tube. The central tube is the digestive tract held in its central position by little thin membranes, or walls, running from each outer constriction. These walls are called **septa** ( ) or **dissepiments** ( ). There are here, then, **many coelomic cavities** which can be clearly seen. It will be remembered that a coelom is defined as the cavity lying **between the digestive tract and the outer body wall.**

There are in the earthworm, muscles, nerves, glands, connective tissue, blood-vessels, epithelium, and endothelium, just as in the frog, though not developed as elaborately. There is also a delicate lifeless coat called the **cuticle.**

THE DIGESTIVE SYSTEM

The alimentary canal (Fig. 166) begins at the anterior end with a **mouth cavity,** or **buccal pouch,** extending from the first to the third somite, inclusively; the thick, muscular **pharynx** ( ) lies in somites four and five; the **oesophagus,** a narrow straight tube,

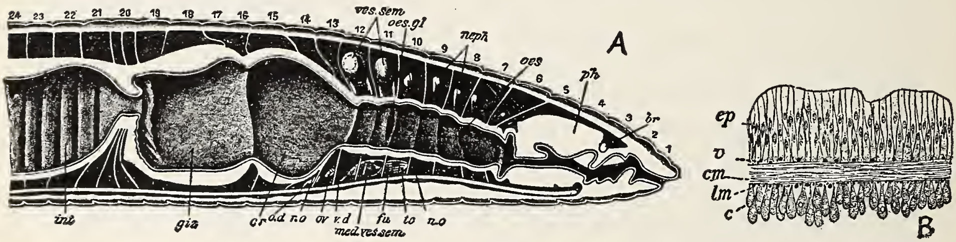


Fig. 166.

A, Longitudinal vertical section through the anterior portion of an earthworm. *br.*, brain; *cr.*, crop; *fu.*, seminal funnel; *giz.*, gizzard; *int.*, intestine; *n.c.*, nerve cord; *neph.*, nephridia; *oes*, oesophagus; *oes. gl.*, oesophageal gland; *ph.*, pharynx. (From Parker and Haswell after Marshall and Hurst.)

B, Section of the Alimentary Canal, *c*, chlorogogen cells; *cm*, circular muscles; *ep*, epithelium, lining the canal; *lm*, longitudinal muscles; *v*, blood vessels. (From Conn, modified from Sedgwick and Wilson.)

extends through the sixth to the fourteenth somite; a thick muscular-walled gizzard in somites seventeen and eighteen; and a thin-walled **intestine** from somite nineteen to the anal opening.

The dorsal wall of the intestine is folded in, forming a longitudinal ridge, called the **typhlosole** ( ). This gives the intestine considerable expansion and affords additional surface for digestion.

The wall of the intestine, as in the frog, is composed of five layers. (Fig. 166, B):

(1) An inner lining of ciliated epithelium,
(2) A vascular layer containing many small blood vessels,
(3) A thin layer of circular muscle fibers,
(4) A layer consisting of a very few longitudinal muscle fibers,
(5) An outer thick coat of **chlorogogen cells** ( ) modified from the coelomic epithelium.

It is supposed that, because these chlorogogen cells lie in the typhlosole close to the dorsal blood vessel, they may aid in some digestive process. Then, because chlorogogen granules are present in the coelomic fluid of adult worms and make their way to the outer part of the body through the dorsal pores, it has been suggested likewise that they may have some excretory function.

Three pairs of **calciferous glands** ( ), one pair in each of the somites from ten to twelve, are found at the sides of the oesophagus. The first pair are pouches, pushed out from the alimentary canal, which open directly into the oesophagus. The other two pairs are swellings of the oesophageal wall. They have a number of small cavities which open directly through the epithelium into the oesophagus in somite fifteen.

One writer thinks these glands manufacture carbonate of lime which is then secreted in the alimentary tract to neutralize the acid foods, while another suggests that the primary function of the glands is merely to excrete calcareous matter derived from leaves on which the animal feeds. This opinion he bases on the fact that such matter accumulates in leaf-tissue and remains in the leaf when it falls. The worms, which take in large quantities of calcareous matter but have no shell or bone, have no use for it, and so "some special excretory apparatus seems necessary." This latter opinion does not oppose the one given immediately preceding it. But the gizzard and intestinal content of worms is, as a rule, acid, so this would seem to oppose both of the above ideas. However, this acidification may be the result of fermentations which occur in the later stages of digestion.

It will thus be seen, that many things must be considered before one can speak on subjects such as these with any degree of authority and positiveness.

As stated, the earthworm feeds on decaying leaves and animal matter. This food is sucked into the buccal cavity.

Here it receives a secretion from the pharyngeal glands, after which it passes through the oesophagus to the crop to be stored temporarily. Secretions from the calciferous glands in the oesophageal walls neutralize the acids. The gizzard is a grinding organ in which the food is broken up into minute fragments by being squeezed and rolled about. Then, too, solid particles, such as rough pebbles, which are frequently swallowed, may aid in the grinding process. The food then passes to the intestine, where most of the digestion and absorption take place.

Digestion in the earthworm is very similar to that of higher animals. The digestive fluids act upon **proteins, carbohydrates,** and **fats.** Special compounds called **ferments** or **enzymes** are in the digestive fluids which break up complex molecules without themselves becoming permanently changed chemically. The three most important enzymes are (1) **trypsin** ( ), which dissolves protein; (2) **diastase** ( ), which breaks up molecules of carbohydrates, and (3) **steapsin** ( ), which acts upon fats. These three enzymes are probably in the digestive fluids of the earthworm. The proteins are changed into peptones, the carbohydrates into a sugar compound, and the fats are divided into glycerin and fatty acids.

After this process has taken place, the food is ready for absorption. This takes place through the wall of the intestine by **osmosis,** assisted by an **amoeboid activity** of some of the epithelial cells.

It will be remembered from our study of the frog that all parts of a living organism must be nourished. The food absorbed is now taken into the circulation and made an actual part of the blood. As there are no blood vessels in some parts of the earthworm, some of the absorbed food is also taken into the coelomic fluid so as to bathe the bloodless areas.

THE CIRCULATORY SYSTEM

The blood of the earthworm, unlike that of man, is actually red, while the corpuscles are colorless. In man the blood-liquid is colorless, and the corpuscles floating about in the blood-plasma are red. This means that the pigment **haemoglobin** ( ) is **within the corpuscle in man** and the higher animals, while it is **in solution in earthworms.**

The following table mentions most of the important longitudinal blood-vessels (Fig. 167):

(1) The **dorsal** or **supra-intestinal,** running along the dorsal surface of the alimentary canal, from the posterior end of the body to the pharynx. It then divides into many small branches.

(2) The **ventral** or **sub-intestinal** trunk, lying just beneath the alimentary canal. It also extends from the posterior end of the body to the pharynx where it divides into many small branches.

(3) **The sub-neural trunk,** as its name implies, passes along under the ventral nerve cord the entire length of the body.

(4) A pair of **lateral-neural trunks** (smaller than those above) lying, one on each side of the ventral nerve cord.

As in the frog and all other vertebrates, **paired** arteries, veins, and nerves, pass toward and away from the spinal cord between the various vertebrae, so in each segment of the earthworm tiny branches of the dorsal and ventral trunks, called **parietal** ( ) branches, pass along the various septa dividing the somites, and connect with the body wall, where they split into fine branching **capillaries** supplying and draining the dermal musculature and epithelium.

Capillaries from the dorsal branch also supply the digestive tract, while in the anterior region two lateral vessels supply the reproductive organs.

It will be remembered that in the study of the frog, the circulatory system began with a three-chambered heart. In the earthworm there is no separate and distinct organ such as the heart. In its place there

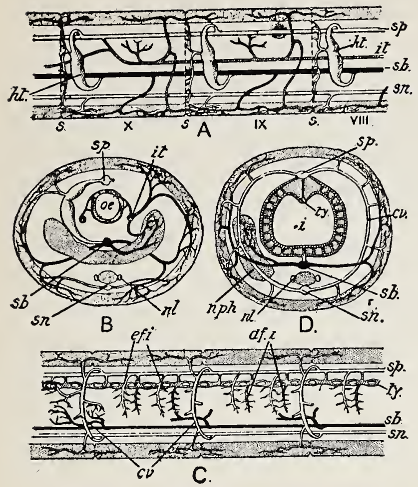


Fig. 167.

A series of diagrams to illustrate the arrangement of the blood-vessels and the course of the circulation in *Lumbricus herculeus*. *A*. Longitudinal view of the vessels in somites 8, 9 and 10. *B*. The blood-vessels as seen in transverse section in the same region. *C*. Longitudinal view of the vessels in the intestinal region. *D*. Transverse section through the intestinal region. *sp*, supra-intestinal; *sb*, sub-intestinal, and *sn*, sub-neural longitudinal trunks; *nl*, lateral neural vessels; *ht, ht*, contractile vessels or "hearts;" *it*, intestino-tegumentary vessels; *cv*, commissural vessels; *af.i*, afferent intestinal vessels; *ef.i*, efferent intestinal vessels; *ty*, typhlosolar vessel; *i*, intestine; *oe*, oesophagus; *s.s.* septa. (After Bourne from a drawing by Dr. W. B. Benham.)

are **five pairs of enlarged vessels** called **aortic arches, aortic loops**, or **"hearts,"** running from the dorsal trunk to the ventral through the seventh, eighth, ninth, tenth and eleventh somites.

These "hearts," as well as the dorsal trunk, furnish the muscular contraction and elongation of circular and longitudinal muscles which force the blood through the vessels. Such rhythmic contraction and expansion in either blood vessels or intestines is known as **peristalsis** ( ).

In the frog there is a **systemic** and **pulmonary circulation.** The earthworm, possessing no lungs, can have no pulmonary circulation.

The blood of the earthworm is **continuous** in closed blood-vessels, so it is called a **closed systemic circulation.**

But, just as there is the closed circulation consisting of heart, arteries, veins and capillaries in the frog, as well as a **lymphatic, open circulation,** by which the lymph passing out of the blood-vessels is able to bathe every part of the body, so we speak of a **coelomic circulation** in the earthworm, which is equivalent to the lymph-like substance outside of the blood-vessels, but within the coelomic cavity of the frog.

The blood is collected from the intestine by two pairs of vessels which enter a longitudinal **typhlosolar tube.** This tube is in turn connected with the dorsal trunk by three or four short tubes in each somite.

As there are no circular muscles in the walls of the ventral trunk, this cannot contract, so the propelling of blood is caused by the dorsal trunk and "hearts" as already stated. This contractile ability of the dorsal trunk and "hearts," together with the fact that there are valves in both of these vessels which permit blood to flow forward but not backward, determines the direction of flow. The valves are just behind the openings of the parietal vessels and in front of the openings of the hearts. There are other valves also, in some of the other vessels, but those just mentioned are the more important in showing how and why the blood flows as it does.

The blood must, therefore, flow forward toward the anterior end of the animal in the dorsal trunk. It is thus forced through the "hearts" and, as it reaches the ventral trunk, is sent both in an anterior and a posterior direction. From the ventral trunk the blood passes to the body wall and nephridia. The lateral neural trunks then receive the blood which has gone to the body-wall, while that having gone to the nephridia has been expelled. The blood in the sub-neural trunk flows posteriorly, then upward through the parietal vessels into the dorsal trunk. The anterior portion of the body receives its nourishment from both dorsal and ventral trunks.

The **Coelomic circulation** consists of the fluid in the coelomic cavities. These cavities are continuous throughout all the somites by means of dorsal apertures or slits occurring between the various septa and the digestive tract. The fluid itself is made up of a colorless plasma with white blood cells or **leucocytes** ( ). This fluid is washed back and forth by the movements of the worm and thus bathes the **endothelial lining** of the coelom.

The amoeboid corpuscles in the coelomic fluid have a remarkable power of attacking bacteria and other microscopic organisms such as gregarines and infusorians or even small nematode worms. If such parasites enter the coelom, the amoeboid cells surround and destroy them. Their operations are, however, not confined to the inside of the earthworm. The slime of the body surface is in part composed of mucus secreted by the skin, and in part of coelomic fluid and its corpuscles which find exit through the dorsal pores. The corpuscles are thus able to attack and destroy bacteria before they effect an entry into the body. There is no doubt that a worm is constantly exposed to these minute organisms for the upper layers of the soil teem with them. The slime itself is a protection, for it both arrests the bacteria and holds them stranded in the trail which the worm leaves behind it in its progress. The application of a grain of some irritant, such as corrosive sublimate, enables one to see how a worm protects itself. As soon as the irritant touches the skin, the segments in front and behind the seat of injury are forcibly constricted, while the affected segment itself swells up in consequence of the increased pressure brought to bear upon it from both sides. At the same time there is a conspicuous gush of coelomic fluid from the dorsal pores in that region and an abundant secretion of mucus from the skin itself. Thus the threatened region is, as it were, isolated by ligatures from the rest of the body and all the defensive resources at once brought to bear upon the enemy. The coelomic fluid is alkaline and contains crystals of calcium carbonate and micro-organisms which, when isolated and reared in artificial cultures, emit the characteristic smell of earthworms. It is, therefore, not improbable that this odor is due to the micro-organisms and not really a feature of the worm itself.

From what has been said above, it will be seen that there is in reality **no true circulation** in the earthworm.

RESPIRATION

The earthworm needs oxygen just as do all animals; but, as it has no lungs, it obtains its oxygen through its **moist outer membrane.** Immediately beneath the cuticle there are many capillaries which present a great expanse of blood area somewhat similar to the many capillaries in the lungs of higher forms. The oxygen here combines with haemoglobin. The blood gets to these capillaries through the vessels supplying the body wall and is then returned to the dorsal trunk by way of the sub-neural trunk and the intestinal connectives.

As the nervous system must **coördinate** every movement of the body, it requires an excellent blood-supply, which is furnished the better in the earthworm by the sub-neural trunk lying very close to the ventral nerve cord. The nervous system is thus continually supplied with fresh nourishment.

THE EXCRETORY SYSTEM

Most of the excretory matter is carried outside the body by a number of **coiled tubes** called **nephridia,** a pair of which lie in each somite except the first three and the last. The dorsal pores also serve as excretory organs to a minor extent.

A clear understanding of the nephridia is important, because such an understanding will serve in good stead in the study of the excretory organs of vertebrates. This is the better understood when it is known that the excretory organs of all higher forms develop from embryological beginnings quite similar to those of the earthworm.

Each nephridium (Fig. 168) consists of:

(1) The funnel or **nephrostome** (   ),
(2) The **ciliated neck,**
(3) The **coiled narrow tube,**
(4) The **wide glandular tube,**
(5) The **ejaculatory duct** opening to the outside.

The ciliated neck of each nephrostome passes through the anterior wall of the somite, close to the mid-ventral line. Each nephrostome, therefore, lies in the somite directly anterior to the one containing its own nephridium, so that waste matters from any one somite are expelled to the outside by the nephridium of the next posterior somite. The nephrostomes, or mouths, of the nephridia are flattened fan-like structures, consisting of two flattened lamellae or plates, with a narrow slit-like opening between them. The large cells, which line the opening, are covered with powerful cilia which maintain a constant current toward the tubular part of the nephridium. These tubes are developed in coils which lie in the posterior parts of the somites. There are three coils or turns in each. The third ends in an enlarged portion opening to the outside on the ventral wall of the somite. All of the turns are well supplied with blood vessels.

An excellent way of demonstrating the action of these nephridic organs is that of injecting carmine powder into the coelom. It will then be observed that this foreign substance is taken up by the chlorogogen cells, which then break down, freeing the carmine together with frag-

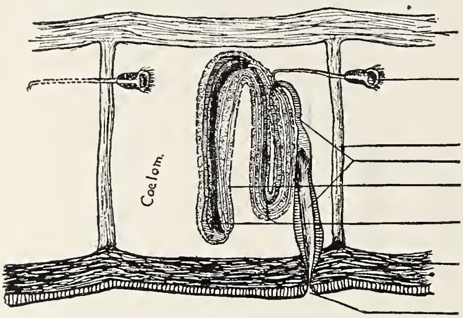


Fig. 168. *Nephridium.*

ments of the chlorogogen cells, and all are caught up by the current made by the nephrostome, and carried through the nephridium to the outside. From this experiment the conclusion has been drawn that some, at least, of the waste matters of the tissues are brought to the chlorogogen cells by the circulation and are acted upon by the fluids of those cells. The products of this activity are liberated into the coelom by the fragmentation of the cells, and then excreted from the worm by the nephridia.

THE NERVOUS SYSTEM

Notwithstanding the nerve cells scattered about in Hydra, it is in the earthworm that we meet with our first **organized nervous system** (Fig. 169). That is, of course, excluding our study of the frog. It will be remembered that the nerve cord was on the dorsal side of the frog. In the earthworm, and all animals lower than vertebrates, **it** lies on the ventral surface. The knowledge of this fact is quite important and will be of use in the later study of evolutionary theories.

Nerves are sensory, motor, or mixed as we saw in the study of the frog. Both sensory and motor nerves run to the muscles of the earthworm, causing reflex action. A reflex action means that an impulse sent toward the central nervous system through a sensory nerve, meets a motor nerve (the meeting place being called a **ganglion**), and the motor impulse is then returned to the place from whence the sensory impulse originated, permitting an organ to move. If such ganglion lies in the **lower** nerve centers, that is, if it lies **caudad to the brain,** so that an impulse from a sensory fiber need not first pass to the brain before meeting the motor fiber, it is called a reflex.

The ventral nerve cord is in reality a **series of ganglia**, one pair lying in each somite posterior to the fourth. Each pair is connected by a nerve cord to the one preceding and following it. In somite four this nerve cord divides into two parts, one passing on each side of the alimentary tract to again unite above the pharynx in the third somite. This **dorsal union** is the **brain**, while the two portions forming it are known as the **circum-pharyngeal connectives**. The **segmental ganglia** forming the nerve cord are called the **sub-pharyngeal ganglia**. The brain and ventral cord form the **central nervous system**. The **nerves** passing from the central nervous system to the various parts of the body, constitute the **peripheral nervous system**.

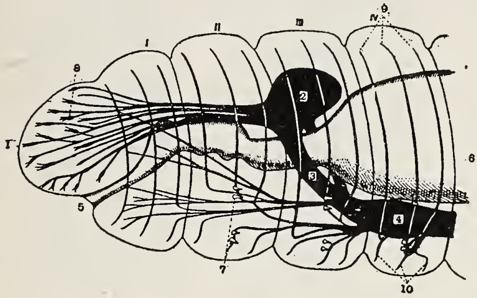


Fig. 169. Diagram of the Anterior End of *Lumbricus Herculeus* to show the Arrangement of the Nervous System.

I, II, III, IV. The first, second, third, and fourth segments.
1. The prostomium. 2. The cerebral ganglia. 3. The circumoral commissure. 4. The first ventral ganglion. 5. The mouth. 6. The pharynx. 7. The dorsal and ventral pair of chaetae. 8. The tactile nerves to the prostomium. 9. The anterior, middle and posterior dorsal nerves. 10. The anterior, middle and posterior ventral nerves. (After Hesse.)

The **supra-pharyngeal** ganglia supply the prostomium with two large nerves which give off many branches; they also send nerves into somites two and three. One nerve extends out from each circum-pharyngeal connective. In each somite, from the fourth to the posterior end of the body, three pairs of nerves arise, two pairs from the ganglionic mass and one pair from the sides of the nerve cord just behind the septum which separates the somite from the one preceding.

Each enlargement of the ventral nerve cord really consists of two ganglia, which are closely fused together. In transverse section these fused ganglia are seen to be surrounded by an outer thin layer of epithelium, the peritoneum, and an inner muscular sheath containing blood vessels and connective tissue as well as muscle fibers. Near the dorsal surface are three large areas, each surrounded by a thick double sheath and containing a bundle of nerve fibers. These are called neurochords or "giant fibers." Large pear-shaped nerve cells are visible near the periphery in the lateral and ventral parts of the ganglion.

The nerves of the peripheral nervous system are **either efferent or afferent**. Efferent nerve fibers are extensions from cells in the ganglia of the central nervous system. They pass out to the muscles or other organs, and, since impulses sent along them give rise to movements, the cells of which they are a part, are said to be motor nerve cells. The afferent fibers originate from nerve cells in the epidermis which are sensory in function, and extend into the vertral nerve cord.

SENSE ORGANS

The sensitiveness of lumbricus to light and other stimuli is due to the presence of a great number of epidermal sense organs. These are groups of sense cells connected with the central nervous system by means of nerve fibers, and communicating with the outside world through sense hairs which penetrate the **cuticle.** More of these sense organs occur at the anterior and posterior ends than in any other region of the body. The epidermis of the earthworm is also supplied with efferent nerve fibers which penetrate between the epidermal cells forming a sub-epidermal network.

THE REPRODUCTIVE SYSTEM

The earthworm, like Hydra, is **hermaphroditic** (Fig. 170) ( ), that is, has both sexes in each animal.

The female reproductive organs, the **ovaries,** lie in somite thirteen, the oviducts in somites thirteen and fourteen, while two pairs of **seminal receptacles** or **spermathecae** lie in somites nine and ten.

The ovaries, which are small pear-shaped bodies lying on either side of the mid-ventral line, are attached by their larger ends to the ventral part of the anterior septum.

The oviducts are made up of various parts. The ciliated funnel lies just posterior to each ovary and passes through the septum, dividing somites thirteen and fourteen, where it has an enlargement known as the **egg sac.** It then narrows into a thin duct which opens to the external part of the body on the ventral surface near the center of somite fourteen.

The **spermathecae** or **seminal receptacles** are white spherical sacs near the ventral body-wall, one pair each in somites nine and ten. These open to the outside through the spermathecal pores lying between somites nine and ten, and ten and eleven.

The male reproductive organs consist of two pairs of glove-shaped **testes,** one pair each in somites ten and eleven. Their positions in the somites are similar to the ovaries. The **vas deferens** ( ), the male organ **homologous** to the female oviduct, is likewise a ciliated funnel serving as the mouth of the duct through which the sperm pass. This lies immediately behind each testis. The duct itself passes through the septum just back of the funnel, where it forms several convolutions, and then extends backward near the ventral surface. The two sperm ducts which arise on either side of the midventral line, unite in somite twelve and then run back as a single tube, opening to the outside through the **spermiducal** pore on somite fifteen. In a sexually mature earthworm, the testes and funnel-shaped inner openings of the sperm ducts are inclosed by large white sacs, the **seminal vesicles,** which lie in somites nine to twelve. There are three pairs of these sperm sacs, one in somite nine, one in somite eleven, and the third in somite twelve. In somites ten and eleven there are central reservoirs.

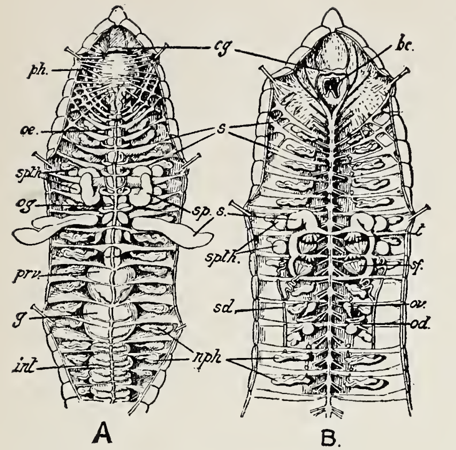


Fig. 170. *Lumbricus Herculeus.*

A. A view of the organs contained in the first twenty-two somites, as seen when the animal is opened by a longitudinal dorsal incision, and the body walls are pinned out without cutting the septa. The pins are placed in the 3rd, 9th, and 18th somites. *B.* View of the first sixteen somites of the same worm after removal of the alimentary tract, to show the nervous system and reproductive organs. *bc,* buccal cavity, cut across; *cg,* cerebral ganglia; *g,* gizzard; *int,* intestine; *nph,* nephridia; *od,* oviduct; *oe,* oesophagus; *ov,* ovary in somite 13; *ph,* pharynx with radiating muscular strands; *prv,* proventriculus; *s,* septa; *sd,* sperm duct; *sf,* seminal funnels; *spth,* spermathecae in somites 9 and 10; *sp.s,* sperm sacs; *t,* testis. (After Bourne.)

The testes are rather difficult to find in a mature worm because they are quite small and the dorsal wall of the vesicle must first be removed.

The sperm are developed in the testes and stored in the seminal vesicles from which they are, during the period of copulation, injected into the seminal receptacles of another worm. Fertilization actually takes place **outside the body.**

When the earthworm is sexually mature, a **clitellum,** or **cingulum,** is formed, covering some six or seven segments. This is a thickened portion often supposed to be a scar formed by the worm after having been injured or cut in two. Mating may take place at any season of the year, but occurs more frequently in warm damp weather.

Again quoting Latter: Two worms from adjacent burrows, "each retaining a firm hold in its own burrow by means of the flattened tail, apply their ventral surfaces to one another so as to overlap for about a third of the length of the body. The head of each worm points toward the tail of the other. The clitellum of each secretes a band of mucus which binds the two worms firmly together, so firmly, indeed, as to cause two well-marked constrictions, while a slimy covering, the slime tube, surrounds the two worms from the 8th to the 33rd segments. The seminal fluid, containing **spermatozoa** ( ) and **spermatophores** ( ), flows within the slime-tube; during sexual union, in the early stages of the formation of the cocoons, spermatophores cover the dorsal and lateral surfaces of segments 9, 10, and 11 of each worm and are packed between the two worms. The spermatozoa flow backwards from the male aperature in a longitudinal groove on each side to the receptacula (spermathecae) of the other worm, the grooves of the two animals together forming a temporary tube. Hence only one worm can emit spermatozoa at any given time, otherwise there would be opposing currents. The worms are so placed that the ninth segment of each is opposite the 32nd (first clitellar) of its mate, then the thickened clitellum forms a barrier past which no flow of seminal fluid can take place.

"The long genital setae in the 'tubercula pubertatis' ( ) of the clitellum, and of segments 10 to 15, are probably used, the former to liberate the cocoon from its seat of origin, and the latter series to hold the cocoon off the ventral surface in the region of the oviducal openings and those of the spermathecae, and thus allow ova and spermatophores to pass into the cocoon as it passes forward. These specialized setae replace those of ordinary form as the worm reaches maturity. The eggs do not pass out of the oviduct till near the end of the act of mating. Each of the two worms forms a cocoon, and slips out of the cocoon backward, passing the cocoon forward over its head. The cocoon being elastic closes its two open ends as soon as the body of the worm is withdrawn, and becomes more or less lemon-shaped, its bulging center being occupied by about four eggs, spermatozoa and albuminous material produced by the so-called capsulogenous glands, which may be seen on the ventral side of some of the segments in front of the clitellum. The cocoons, at first white but soon becoming yellow, are left in the earth, and as a rule only one of the contained eggs produces a young worm. The size of the cocoons differs in the various species, those of L. terrestris are from 6 to 8 mm. long by 4 to 6 mm. broad, of Eisenia foetida from 4 to 6 mm. long by 2 to 3 mm. broad. There is some doubt as to the precise function of the spermathecae. It seems certain that the spermatozoa contained in them, are derived from some other worm. It is also the case that these organs are full of spermatozoa prior to sexual union, and are empty subsequent to that act, at any rate when cocoons are formed and eggs deposited. Worms have been observed to separate without producing cocoons, and though perhaps in some instances the separation may have been due to disturbance caused by observation, yet there is reason to think that two unions are necessary, one to fill the spermathecae, and a second to form cocoons. In such a case it is probable that each worm acts as a carrier of spermatozoa from its first to its second mate, i. e., worm A gets its spremathecae filled by the spermatozoa of B in the first union, and passes these spermatozoa to C in the second. The actions are probably often reciprocal. According to Goehlich, while spermatozoa are flowing from one worm to the spermathecae of the other, there is given out from the spermathecae of the former a small quantity of mucus which hardens when it reaches the air. A second portion of mucus, containing a group of spermatozoa, is then emitted. This becomes attached to the first mass, and with it forms a spermatophore. The whole spermatophore is attached to the body of the other worm close to the clitellum. When the cocoon is made, the spermatophores are rubbed off into it as the animal withdraws itself.

"Light could probably be thrown on this matter by some such experiments as follow: Keep a number of worms, each in a separate flower-pot, from infancy to maturity; kill a few and examine the contents of their spermathecae (it is conceivable that a worm may be able to pass spermatozoa into its own spermathecae); allow the remainder to mate once, and note if cocoons are deposited; kill some and examine the contents of spermathecae; allow the rest to mate a second time, pairing some with their former mates and others with different mates. Kill all and examine spermathecae."

In plants and animals, where both sperm and eggs are found in the same individual, there is usually a different period for the maturing of each, or some apparatus like this of the earthworm is brought into play so that it is very seldom that the same organism can fertilize itself.

The **sperm-mother cells** are derived from the testes and deposited in the seminal vesicles. They are not fully developed, or as we say, "mature," however, when they leave the testes, and so must continue their development in the seminal vesicles.

The sperm-mother cells, or **primordial germ-cells,** from which the sperm are developed in the testes, have their nuclei divide into 2, 4, 8, or 16 daughter nuclei which become arranged in a single layer near the periphery of the protoplasm which has not divided. Cell walls then appear, extending inward into the undivided protoplasmic mass. These newly-formed cells now divide again, forming as high as from 32 to 128 cells, when the whole mass breaks up into smaller colonies. These nucleated cells, which are to become sperm, are called **spermatogonia.** These spermatogonial colonies become spherical, each containing 32 primary **spermatocytes,** all of which are still fastened by **cytoplasmic threads** to the central protoplasm. This whole 32 celled colony is now called a **blastophore.**

Each colony of primary spermatocytes causes the formation of 64 **secondary spermatocytes,** and these divide into 128 **spermatids.** The latter then **metamorphose** ( ) into **spermatozoa.** The number of chromosomes in the spermatozoa is sixteen. This is one-half the number contained in the **somatic cells,** a reduction having taken place during **maturation** by the union of the chromosomes two by two in the secondary spermatocytes, and a subsequent separation when the spermatids were formed.

The head of the spermatozoon is practically all nuclear material. The mid-piece is what was formerly the centrosome, while the cytoplasm formed the tail. But as it is only the head which actually enters and fertilizes the egg, the tail being used only for locomotive purposes, it will be seen why nuclear material is considered so very important.

OOGENESIS

The egg-mother cells are found in the ovary in various stages of growth, beginning at the basal end of each ovary where the most primi-

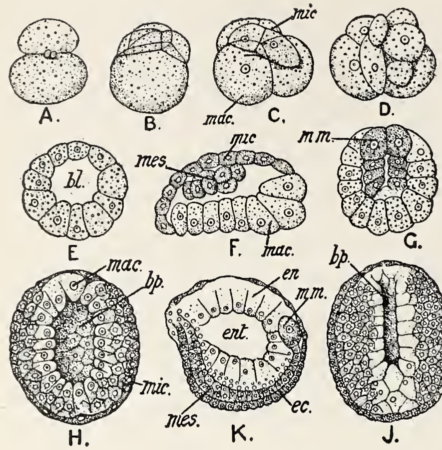


Fig. 171.

Segmentation and early stages of development of *Lumbricus*. *A, B, C, D,* successive stages of segmentation. *E.* Blastula stage. *F.* Commencement of invagination; the macromeres form a flat plate on the ventral side. *G.* An embryo somewhat younger than *F.* viewed from above, showing the mesomeres and mesoblast rows derived from them. *H.* Gastrula stage viewed from below, showing the wide oval blastopore bounded by macromeres; at the sides the micromeres are growing over the macromeres. *J.* Later stage, showing the elongated blastopore and the further overgrowth of the macromeres by the micromeres. *K.* Optical longitudinal section through a later stage after the closure of the blastopore. *bp,* blastopore; *ec,* ectoderm; *en,* endoderm; *ent,* enteron; *mac,* macromeres; *mes,* mesoblast; *mic,* micromeres; *mm,* mesomeres. (From Bourne after Wilson.)

tive germ-cells are found. The ova increase in size toward the extreme end, where the germ-cells are distinctly recognizable as eggs. Each egg is surrounded by a follicle ( ) of nutritive cells. The eggs separate from the end of the ovary and dropping into the body-cavity, pass into the ciliated end of the oviduct which leads to the egg-sac where part of the maturation takes place. From here they either pass out into the cavity of the slime-tube and are conveyed from the external openings of the oviduct in somite 14 to the cocoon, or they enter the cocoon itself when it passes over this somite during deposition. The eggs are actually fertilized by the spermatozoa **after** the cocoon is shed and before the egg has completed its maturation process.

EMBRYOLOGY

The egg of the earthworm is **holoblastic** (Fig. 171) although **cleavage is unequal,** the first division resulting in one large and one small cell. The second cleavage divides the small cell into two equal parts, but cuts off only a small portion from the larger one. The small cells are called **micromeres,** and the large ones **macromeres.** Cleavage is very irregular after this second division. The micromeres are the **animal cells,** and the macromeres the **vegetative cells.**

A cavity, the **blastocoele,** soon forms between micromeres and macromeres, resulting in a **blastula.**

Two of the larger cells of the blastula project down into the blastocoele. These continue dividing and form two rows of small cells from which the mesoderm is to form. They are, therefore, called **mesomeres,** while the two rows formed from them are known as **mesoblastic bands.** During the time these bands are forming, the blastula becomes flattened, the larger cells form a plate of **clear columnar cells,** and the small cells spread out into a thin dome-shaped **epithelium.**

The mesomeres lie toward the posterior end of the blastula, and the mesoblastic bands lie along the **longitudinal axis** of the worm, showing the beginnings of **bilateral symmetry.**

A gastrula is now formed by the **invagination** of the plate of large cells, this invagination continuing until only a slit remains. This tiny opening or slit is called the **blastopore,** while the cavity is the **enteron.**

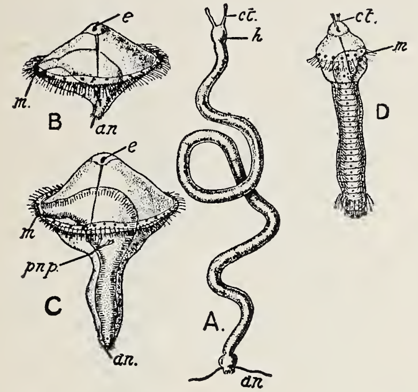


Fig. 172. *Polygordius Appendiculatus.* A, dorsal view. *an,* anus; *ct,* cephalic tentacles; *h,* head. *B,* trochosphere larva. *an,* anus; *e,* eye-spot; *m,* mouth. C and D, stages in development of trochosphere into the worm. *pnp,* pronephridium. (From Bourne, after Fraipont.)

Fig. 173. *Nereis Pelagica,* L. (After Oersted.)

There are now **three germ-layers.** The mid-layer or **mesoderm** already began forming **before gastrulation.**

The large clear cells which invaginated have become the inner lining of the enteron and form the **entoderm;** the outer portion is **ectoderm,** while the **mesoderm** is made up of the two mesoblastic bands which lie between ectoderm and entoderm.

As the earthworm is to be our example of the **coelomates,** it is of value here to observe how the coelom is formed.

The mesoderm separates into the two layers on each side of the body. A cavity forms between these layers. **This cavity is the coelom.** The outer portion of the divided mesoderm is called the **somatopleure** (   ), the inner layer the **splanchnopleure** (   ).

The **muscles of the body-wall** are formed **from the somatopleure,** while **the splanchnopleure forms the muscles of the alimentary canal.** After the germ-layers are formed, the embryo elongates, the anterior-posterior axis passing through the blastopore. There are various **in-pushings from the ectoderm** which become the **elements of the nervous system.** Such beginning cells are called **neuroblasts** if they form nerves.

There are also **separations from the mesoderm** forming **nephroblasts** if they form nephridia, **somatoblasts** if they form muscles, etc.

The ectoderm turns in at both anterior and posterior ends, the former forming the mouth or **stomodeum** ( ), the latter the anal opening or **proctodeum** ( ).

The **chlorogogen cells** are formed **from mesoderm**, as are also the **blood-vessels, muscles, reproductive organs** and **seta sacs.** The young worm is now ready for an independent life and leaves the cocoon after from two to three weeks.

The following table will give a summary of the important tissues derived from the various germ-layers:

ENTODERM	ECTODERM	MESODERM
Oesophagus,	Outer Epithelium,	Muscles,
Crop,	Nervous System,	Coelomic Endothelium,
Gizzard.	Stomodeum,	Chlorogogen Cells,
	Proctodeum,	Calciferous Glands,
	Ends of Nephridia.	Blood vessels,
		Septa,
		Nephridia, functional parts,
		Seta Sacs,
		Reproductive Organs.

BEHAVIOR

As shown by their home-life, worms are apparently fond of having their bodies in contact with solid objects. Moisture causes a positive reaction if such moisture comes in direct contact with the worm's body. This is well illustrated by placing the earthworm, **Allobophora foetida** (the small manure worm), on a piece of dry filter paper when it will not react, but as soon as moisture is applied it begins to burrow, provided this moisture or liquid is taken from manure.

Darwin supposed that the earthworm's ability to distinguish edible from inedible food lay in the sense of contact. This would make **contact** in the earthworm act as a sort of **taste organ.** Various chemicals which cause a reaction, may be due to this sort of secondary taste-ability.

While there are no eyes, light causes the animal to react. This is shown by its moving away from lighted areas. The manure worm, however, will respond **positively** to a very **faint light.** The preferable colors, when very faint, are red, green and blue in the order given, though it does not follow from this that the earthworm can distinguish colors. Its ability consists, in all probability, of "feeling" different rays of light as well as different intensities.

It has also been noted that, if a previous stimulus is much stronger than a succeeding one, the first will naturally continue to react and cause either no reaction to a second or at least lessen such reaction. An example of this is found when the animal is feeding or mating. Light which under normal conditions causes a negative reaction, may have no effect whatever under such circumstances, the **instinctive reaction of the primary instinct** being stronger than the artificial secondary stimulus.

REGENERATION

Any part of an earthworm may be cut off at any point between the end of the prostomium and the fifteenth to the eighteenth segment and a new anterior end will grow out from the cut end of the body. This will consist of a single segment if only one segment was removed; two segments, if two segments were removed; and of three, four, or five segments, if three, four, or five segments were removed. But never more than segments one to five are regenerated, regardless of the number removed, and no new reproductive organs appear if the original ones were contained in the severed piece. If the cut is made behind segment eighteen, a tail will grow out from the cut surface of the posterior piece, thus producing a worm consisting of two tails joined at the center. Such a creature cannot take in food, and must slowly starve to death. When the regenerated part is different from the part removed, as in the case just cited, the term **heteromorphosis** is given to the phenomenon.

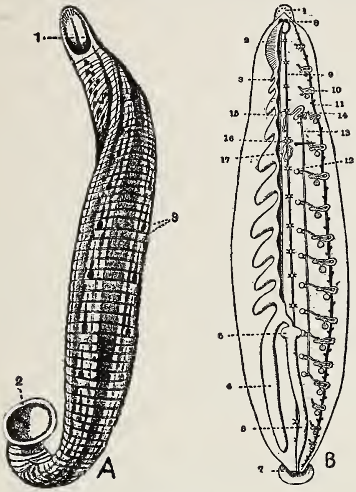


Fig. 174.

A. Hirudo medicinalis, about life size.
1. Mouth. 2. Posterior sucker. 3. Sensory papillae on the anterior annulus of each segment. The remaining four annuli which make up each true segment are indicated by the markings on the dorsal surface.
B. View of the internal organs of *Hirudo medicinalis.* On the left side the alimentary canal is shown, but the right half of this organ has been removed to show the excretory and reproductive organs.
1. Head with eye spots. 2. Muscular pharynx. 3. 1st diverticulum of the crop. 4. 11th diverticulum of the crop. 5. Stomach. 6. Rectum. 7. Anus. 8. Cerebral ganglia. 9. Ventral nerve cord. 10. Nephridium. 11. Lateral blood-vessel. 12. Testis. 13. Vas deferens. 14. Prostate gland. 15. Penis. 16. Ovary. 17. Uterus—a dilatation formed by the conjoined oviducts. (After Shipley and MacBride.)

Regeneration of a tail differs from that of a head, since more than five segments can be replaced. The anal segment develops first, and then a number of new segments are introduced between it and the old tissue.

The rate of regenerative growth depends upon the amount of old tissue removed. If only a few segments of the posterior end are cut off, a new tail regenerates very slowly; if more are removed, the new tissue is added more rapidly. In fact, the rate of growth increases up to a certain point as the amount removed increases. The factors regulating the rate of regeneration have not been fully determined, although several possible explanations have been suggested.

GRAFTING

Pieces of earthworms may be grafted upon other worms without much difficulty. Three pieces may be so united as to produce a very long worm; the tail of one animal may be grafted upon the side of another, producing a double-tailed worm; or the anterior end of one individual may be united with that of another. In all such experiments the parts must be held together by threads until they become united.

The Annelida are divided into three classes, as follows:

(1) **Class Archiannelida** (Gr. **arche**, beginning—Lat. **annellus**, ring). The **Polygordius** (Fig. 172) is the typical example. This class is without **setae** or **parapodia.**

(2) **Class Chaetopoda** (Gr. **chaite**, bristle—**pous**, foot). **Nereis**, the common sand-worm, and the earthworm are classic examples. **Nereis** differs from the earthworm in having a pair of **chitinous jaws**, a **pair of tentacles**, and **two pairs of eyes** on the prostomium, as well as in having a pair of **palpi**, and four pairs of **tentacles** on the peristome. The **parapodia** are used for locomotion, while the **lobes of the parapodia** are well supplied with blood-vessels and serve as **gills.** Then, too, there are **jointed locomotor-setae** on each parapodium, while the muscles which move the parapodium, are attached to two buried bristles, called **aciculae**, which serve as a sort of internal skeleton. The sense organs of **Nereis** are also developed more highly than those of **Lumbricus**, the tentacles serving as organs of touch, while the palpi are thought to act as organs of taste, and the eyes, of sight.

Nereis (Fig. 173) is the example of the **sub-class** known as **Polychaeta** (on account of its many foot-like structures), while such worm-like water-animals as **Tubifex, Dero**, and **Nais**, usually serve as the example of the sub-class, **Oligochaeta** (having few setae).

(3) **Class Hirudinea.** (Lat. **hirudo**, leech.) These are worm-like animals living in fresh water and on land. They are commonly called **leeches.** They are flattened **dorso-ventrally.** The external segmentation does not correspond to the internal segmentation. The leeches are distinguished from the earthworm by having definitely **thirty-three segments, two suckers** (one at each end), and **no setae** (except in one genus). They are hermaphrodites.

The most important example is the medicinal leech, known as **Hirudo medicinalis** (Fig. 174), normally about four inches long, though capable of much contraction and expansion. Not only are these animals used to draw blood from patients, but Lambart advises against drinking water which is not filtered, especially in the tropics, as the small leeches may be swallowed. When swallowed, they attach themselves below the larynx and, instead of releasing themselves when filled with blood as they do on an external surface, they seem to draw a small amount of blood and then migrate to another spot close by and begin the same process, thus causing considerable **anaemia** (loss of blood).

This is readily understandable when it is realized that the leech has three chitinous jaws to form the mouth (which lies within the anterior sucker). These jaws bite into a region, and a secretion from the mouth-glands is poured out which prevents the host's blood from coagulating. It is thus difficult to stop the bleeding after the animal has moved to a new location.

The digestive tract of the leech is especially adapted to the digestion of blood of vertebrates, upon which the leech feeds. There is a **muscular pharynx** and a **short oesophagus** leading to the **crop.** This crop has **eleven branches** or diverticulae. Then there is a **stomach,** an **intestine,** and an **anus.** The leech can ingest blood to the amount of about three times its own weight.

A peculiar kind of connective tissue, known as **botryoidal** ( ) **tissue,** develops in what should be the coelom. This body-cavity is, therefore, very small. There are also spaces in the coelom, called **sinuses,** which are not filled with this tissue.

There are **seventeen pairs of nephridia,** quite like those of the earthworm (except that they sometimes do not have an internal opening) which carry waste products from the coelomic fluid and from the blood. Respiration takes place at the surface of the body through the many blood-capillaries found in the skin.

There are **nine pairs of segmentally arranged testes** which empty their sperm into the **vas deferens,** then into a much-folded tubule called the **epididymis.** Here they are fastened into bundles known as **spermatophores.** They are then ready to fertilize the eggs of another leech, after passing out of the copulatory organ.

The eggs develop in a single pair of ovaries, from which they pass through the **oviducts** into the **uterus,** and finally out through the **genital pore** situated on the ventral side of the ninth segment. A cocoon is formed after copulation quite like that in earthworms.

CHAPTER XX

FLATWORMS (PLATYHELMINTHES) AND THREADWORMS (NEMATHELMINTHES)

CONSIDERED systematically the flatworms and round worms should be placed before the earthworm as **they are not coelomates.** But, as the average man always thinks of a sort of segmented animal similar to an earthworm when worms are mentioned, and medical men likewise are not very accurate when they discuss these animals, the student is more likely to remember the three types of worms if he thinks of them all at once and notes their similarities and differences.

With the exception of the leech **(Hirudo medicinalis)** commonly used to draw blood, the annelids are of little importance from a medical standpoint. However, the flatworms and round unsegmented worms have come to have a very considerable bearing on the human being from a pathological standpoint.

THE FLATWORMS

The **flatworms** (which constitute the phylum **Platyhelminthes)** are subdivided into the following three classes:

Class I. **Turbellaria** (Lat. turbo, I disturb), with ciliated ectoderm; free-living habit, example: **Planaria.**

Class II. **Trematoda** (Gr. trema, a pore; eidos, resemblance), with non-ciliated ectoderm; suckers; parasitic habit, example: **Fasciola hepatica** (liver fluke), and

Class III. **Cestoda** (Gr. kestos, a girdle; eidos, resemblance), with body of segments; without mouth or alimentary canal; parasitic, example: **Taenia** (tapeworm).

TURBELLARIA

Turbellaria are the only flatworms which are not parasitic. They live on the lower surface of submerged stones and debris close to the margin of ponds, springs and lakes. Most of these are **Planaria** (Fig. 175), but often a longer worm is found (from ten to fifteen millimeters), which is called **Dendrocoelum lacteum.**

Planaria crawl about among aquatic plants to seek food. The cilia covering the ectoderm assist in this movement, though the animal also contracts and expands its body. As soon as **Planaria** finds a small animal suitable for its food, the **proboscis,** lying near the center of the body, is practically turned inside out through the mouth. This proboscis grasps the food and draws it into the body. As the mouth is near the center of the ventral surface, the proboscis can be extended in any direction.

The digestive system consists of the **mouth, proboscis or pharynx** (which lies in a muscular sheath), and three chief interior intestinal branches, one running forward to the head end of the body and two leading tailward. Many small side pouches, or diverticula, protrude. In fact, every part of the body has such a pouch. This means that all parts of the body can take nourishment immediately from the digestive tract so that **Planaria** need no circulatory system. All non-digested food must be egested through the mouth as there is no anal opening.

In some forms a definite green substance appears, due to **the zoöchlorellae** or **symbiotic one-celled plants** which live in the middle germ-layer.

Food is digested both **intercellularly** and **intracellularly,** which means that a part of the food is digested **in the intestine proper** by secretions poured out from cells in the intestinal walls; and, that food may also be digested by pseudopodia extending from cells in the intestinal walls. In the latter case the pseudopodia take in the undigested food to the cell which then digests it.

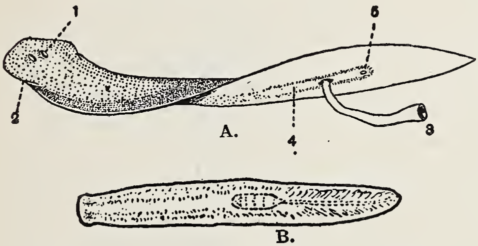


Fig. 175. *A. Planaria polychroa* × about 4.

1. Eye. 2. Ciliated slit at side of head. 3. Mouth of proboscis. 4. Outline of the pharynx sheath into which the pharynx can be withdrawn. 5. Reproductive pore.
B. Dendrocoelum graffi. (Woodworth.)

External Appearance.

Planaria is bilaterally symmetrical and dorso-ventrally flattened. The head-end is blunt and the tail-end tapers. It is usually less than half an inch in length. The common American species is known as **Planaria maculata.** It has a definite pair of **eye-spots.**

Turbellaria are metazoans and triploblastic. The mesoderm consists mostly of muscles and loose parenchyma cells. The coelom is represented by the genital sacs.

Turbellaria are classified according to the type and number of branches found in the digestive tract.

In some turbellaria, though not in planaria, there are special ectodermal cells which secrete mucus, or produce rod-like bodies called **rhabdites.**

The Excretory System.

The excretory system (Fig. 176) consists of two irregular, longitudinal, much-coiled tubes, one on each side of the body. Near the anterior end, these two tubes are connected by a transverse vessel. The longitudinal vessels open to the exterior by two small pores on the dorsal surface of the animal.

Many fine tubules branch off from these main tubes and ramify through all parts of the body, terminating in large **flame-cells** (Fig. 177).

Each of these flame-cells (which are characteristic of the flatworms) consists of a central cavity into which a bundle of cilia project. The flickering of the cilia look something like a candle-flame, and it is this shape which give them their name. It is the flame-cell which is considered the real excretory organ of the animal, though some writers think it may also have some respiratory functions.

The Nervous System.

There are two lobes (Fig. 176) of nervous tissue beneath the eye-spots. These are usually called the brain. There are also two longitudinal **nerve-cords,** one on each side of the body, connected by transverse nerves. Nerve branches pass into the head proper from the brain region, so that the anterior end becomes the more sensitive.

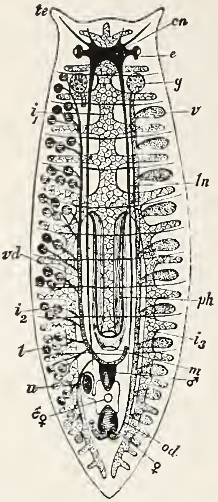


Fig. 176. Anatomy of a Flatworm.
cn, brain; *e,* eye; *g,* ovary; i_1, i_2, i_3, branches of intestine; *ln,* lateral nerve; *m,* mouth; *od,* oviduct; *ph,* pharynx; *t,* testis; *u,* uterus; *v,* yolk glands; *vd,* vas deferens; ♂, penis; ♀, vagina; ♂, ♀, common genital pore. (From Lankester's Treatise, after v. Graff.)

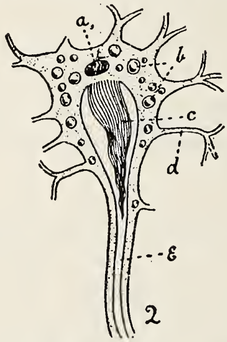


Fig. 177. Flame-cell of *Planaria.*
c, cilia; *e,* opening into the excretory tubule. (From Lankester's Treatise.)

The Muscular System.

Immediately beneath the ectoderm, a group of muscles form a **dermo-muscular sac** around the internal organs. There are two layers, an inner longitudinal, and an outer circular layer.

The Reproductive System.

Planaria are **hermaphroditic,** having both male and female reproductive organs (Fig. 176). These animals nevertheless often reproduce by **fission.** Each animal has numerous spherical testes which are connected by small tubules called **vasa deferentia.** The single vas deferens from each side of the body empties into, or through, the **cirrus** into the **genital cloaca.**

At the base of the cirrus there are a **seminal vesicle** and several unicellular **prostate glands.**

After the sperm are formed in the testes, they pass to the seminal vesicle through the vasa deferentia, and remain there until needed for fertilization.

The ovaries are two in number. From these the two long oviducts (which possess many yolk-glands) connect with the vagina. The vagina opens into the genital cloaca. The uterus also connects with the cloaca.

After the eggs ripen, they pass from the ovary through the oviducts (where they collect yolk from the yolk-glands) and finally reach the uterus. Fertilization occurs in the uterus. Cocoons are formed, each containing from four to twenty eggs and several hundred yolk-cells.

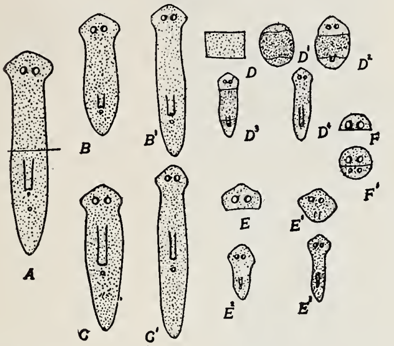


Fig. 178. Regeneration of *Planaria maculata*. *A*, normal worm. *B*, B^1, regeneration of anterior half. *C*, C^1, regeneration of posterior half. *D*, cross-piece of worm. D^1, D^2, D^3, D^4, regeneration of same. *E*, old head. E^1, E^2, E^3, regeneration of same. *F*, F^1, regeneration of new head on posterior end of old head. (From Hegner after Morgan.)

As already stated, **Planaria** may also reproduce by fission. This means in this instance that when the hindermost portion of the animal is grown, it breaks off from the fore part to produce a new animal.

Regeneration.

From the laboratory point of view, **Planaria** is probably the most available animal one can find to show regeneration experiments. This is especially true because the parts to be regenerated grow very rapidly, each day marking a definite growth region.

Almost any part of the animal will re-grow, but there are portions quite specialized in **what** is re-grown. If, for example, the head is cut off directly behind the eyes, the more anterior part will regenerate a new head but no body, thus making a two-headed animal. Such specialization is called **polarity.** (Fig. 178.)

Two types of eggs are laid. In the summer the eggs are thin-shelled and develop quickly, while in the autumn the "winter eggs" are laid. These are thick-shelled and lie dormant until spring before hatching.

TREMATODA

All the trematodes are parasitic. Some are **monogenetic**; that is, the adults lay eggs which hatch into forms like their parents, all living on the outside of their host. These are said to have a **simple life-history.** This type of animal is usually found on cold-blooded vertebrates, such as frogs, fishes, etc.

The **endoparasitic** trematodes (those which live in the internal organs of a host, whether that be in the liver, lungs, intestines, bladder or other similar internal structure), are mostly **digenetic.** This means that the parasite must pass through more hosts than one to complete its life cycle.

The liver fluke, **Fasciola hepatica** (Fig. 179) is the form usually studied in the laboratory.

The adult liver fluke lives in the bile-ducts of the sheep's liver and is continually laying eggs which are carried through the intestine of the host to the outside in the faeces. If these eggs become moist they

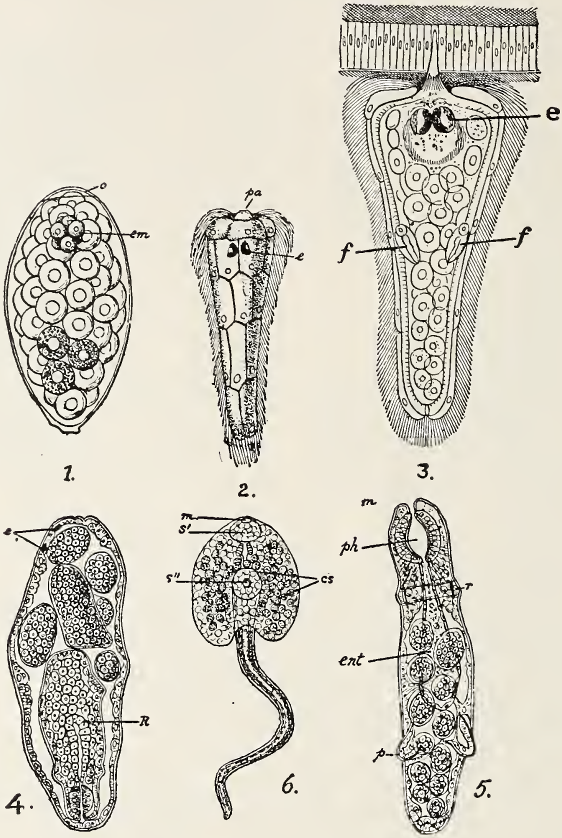


Fig. 179. Stages in the Life-History of the Liver Fluke, *Distomum Hepaticum.*

1, Egg filled with large vitelline cells in which the segmenting ovum, *em.*, is embedded; *o.*, operculum; 2, Miracidium larva with large ciliated cells, the eyespot *e.*, and the interior papilla, *pa.* 3, Miracidium boring its way into the tissues of *Limnaea; f-f.*, flame cells. 4, a sporocyst containing one fully developed and several developing rediae *(R.); e.*, the degenerate eyes. 5, a redia containing several daughter rediae in various stages of development; *m.*, mouth; *ph.*, pharynx; *ent.*, enteron; *r.*, muscle collar; *p.*, posterior processes. 6, a cercaria; *m.*, mouth; *s'.*, anterior, and *s''.*, posterior suckers; *cs.*, cystogenous cells. (After Thomas.)

hatch into tiny **ciliated larvae** called **miracidia.** These larvae swim about until they find a **pond snail.** This found, the larvae bore their way into the snail where a complete change takes place in the parasite. It takes about two weeks for the fluke larvae to form a sac-like **sporocyst.** Each germ-cell in this sporocyst passes through a blastula and gastrula stage and then becomes a second kind of larva which is now called a

redia. These **rediae** then break through the sporocyst and enter the host's liver. The rediae have germ-cells within them, and these germ-cells give rise to little **cercaria** which look something like tiny tadpoles. These tadpole-like cercaria leave the snail and swim to the shore to form cysts on surrounding vegetation.

As the sheep pass along and eat the vegetation bearing these cysts,

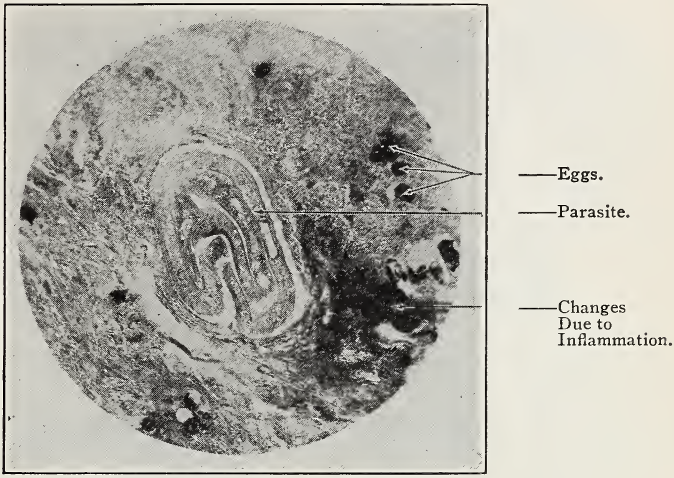


Fig. 180. *Schistosomum Haematobium.*
(Distoma Haematobium.)
From the submucosa of the large intestine of man.
(From a photograph lent the author by
Dr. E. L. Miloslavich.)

the life-cycle is again begun. It will be noted from the account just given that the larval stages breed in cold-blooded animals, while the adult stages must have warm-blooded animals for their hosts.

The liver fluke is by no means unknown to affect the human liver, and where this is known to be the case, great care must be exercised in eating uncooked vegetables.

From the complicated life-cycle the liver fluke displays, it can readily be understood that many thousands of eggs must be produced by a single animal if liver flukes are not to die out; for, it is not at all likely that many of the miracidia will find a snail host; and then again, it is not very likely that many of the cysts on the shore vegetation will be eaten by sheep.

One liver fluke will produce as high as five hundred thousand eggs, and a single sheep may contain over two hundred adult flukes. This means that over a hundred million of eggs may develop in a single sheep.

Trematode Infections.

Schistosomum haematobium (Fig. 180), (also called **Bilharzia haematobia**), which causes the disease known as **bilharziosis**, is by no means uncommon in tropical countries such as Asia and Africa, and is sometimes found in Europe and America.

The mature worm lives in the branches of the portal veins so that the eggs are easily distributed (with the blood) into the liver and other organs of the body. The eggs, which are the true cause of the disease, have a tendency to affect the urinary apparatus, causing a bloody urine to be discharged and also causing destructive and over-growth processes in the bladder, urethra, and surrounding parts. All these infected parts are loaded with eggs so that abscesses and fistulas form. Similar conditions may take place in the rectum. Ten per cent of all patients in Cairo were found to be infected, while seven and a half per cent of all army recruits in Egypt showed the eggs in their urine.

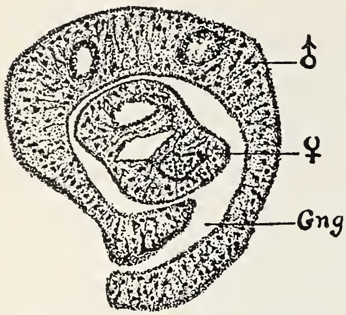


Fig. 181. Schistosoma Japonicum.

♂, male, containing the female, ♀, in the gynaecophorous groove, *gng.* (After Rivas.)

Schistosomum Japonicum is the Japanese species.

This blood-fluke is peculiar in that it has separate sexes, the male being carried about by the female in a **gynaecophorous canal** (Fig. 181).

The eggs are oval and a **terminal spine** is found at one end. The eggs hatch in water, so they may be taken in with raw vegetables or even with drinking water.

It is an interesting fact that **animal parasites often cause no pain,** but are on that very account the more dangerous. The patient infected pays no attention to his infection, and the disease grows constantly worse because no remedial measures are taken.

Schistosoma japonicum vel cattoi. This species is common in China, Japan, and the Philippines. The disease produced by it is called **Katayama disease.** The liver hardens and the spleen enlarges. There is dysentery and loss of blood. The eggs are smaller than **S. haematobium,** and the species do not have the terminal spine.

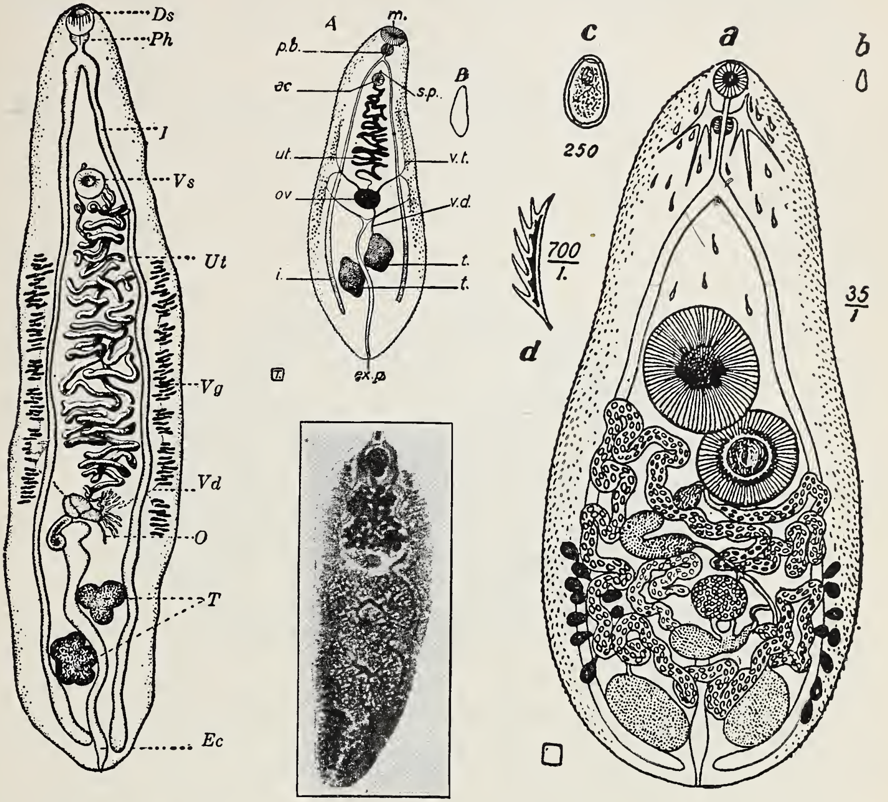
In Formosa, **Paragonimus Westermani** (Fig. 182), (Asiatic lung-fluke or bronchial fluke), is often found as a parasite infecting the lungs of man. It is also found in the brain where it causes death from pressure.

The worm is from 8 to 16 mm. long and from 4 to 8 mm. broad, and is pinkish or red in color. The disease it causes is often confused with tuberculosis, although the microscope shows many eggs in the sputum. The liver, brain, and eyelid are the points most commonly affected.

The common liver-fluke, **Fasciola hepatica,** though rare in the United States, is common in Syria where men eat raw goat-livers. The disease is called Halzoun.

Opisthorchis (Distoma) felineus is common in cats. It has been found in Prussia, Siberia, and Nebraska.

Opisthorchis noverca (Distomum conjunctum) is the Indian liver-fluke.



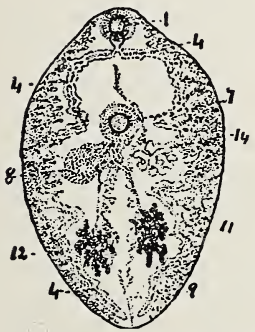


Fig. 182. Infective Trematodes.

I. *Opisthorchis felineus.* *Os.*, oral sucker; *Ph.*, pharynx; *I.*, intestine; *Vs.*, ventral sucker; *Ut.*, uterus; *Vg.*, vitelline glands; *Vd.*, vitelline duct; *O.*, ovary; *T.*, testes; *Ec.*, excretory canal.

II. *Opisthorchis noverca.* *A.*, greatly enlarged. *B.*, almost natural size. *m.*, mouth (oral sucker); *ph.*, pharynx; *ac.*, acetabulum (ventral sucker); *ut.*, uterus; *vt.*, vitelline glands; *ov.*, ovary; *vd.*, vas deferens; *t.*, testes; *i.*, intestine; *exp.*, excretory pore.

III. *Fasciolopsis buski.*

IV. *Heterophyes heterophyes.* *a.*, schematic and highly enlarged; *b.*, about twice natural size; *e.*, eggs, greatly magnified; *d.*, spine greatly magnified. (I, after Stiles and Hassal; II, after Manson; III, after Rivas; IV, after Loose.)

V. *Paragonimus Westermani* (Asiatic Lung Fluke): 1, oral sucker; 4, intestine; 7, acetabulum; 8, ovary; 9, excretory canal; 11, yolkglands; 12, testis; 14, uterus. (After Pratt.)

Opisthorchis (Distoma) sinensis. This is one of the most important of liver-flukes. It occurs extensively in Japan, China, and India. It is from 10 to 20 mm. long and from 2 to 5 mm. broad. The eggs are oval and dark-brown, with sharply defined operculum. **O. sinensis** are also found in Canada and the United States. Children are usually affected, and whole villages succumb to its ravages.

Fasciolopsis (Distoma) buski is common in India, and **Mesogonimus heterophyes** in Egypt and Japan.

CESTODA

The common tapeworm, **Taenia solium** (pork tapeworm), (Fig. 183), is the best laboratory example of **Cestoda.** It lives in the digestive tract of man and feeds upon the already digested food of its host. The tapeworm, therefore, needs no digestive system of its own, and it has none.

Taenia is a long flatworm consisting of a knob-like head, called the **scolex**, and a great number of segments which are all like each other but different from the scolex. These segments are known as **proglottids.**

Hooks and **suckers** on the scolex permit the animal to fasten itself to the walls of the digestive tract of its host. A small constriction between head and proglottids is called the neck. The proglottids usually increase in size the further they are from the scolex. It is not uncommon to have a tapeworm reach ten or more feet in length and have some eight or nine hundred proglottids. The proglottids are budded off from the neck, so that the segments furthest from the head are the older. The process of forming new proglottids is called **strobilization.**

The body of the simplest type of tapeworm is not segmented, though most forms are.

Each proglottid contains a set of both male and female reproductive organs, but the nervous and excretory systems are usually quite continuous through head and proglottids. The question often arises as to whether each segment is not a complete individual, but the best authorities believe that the scolex is an asexual individual which buds off the sexual individuals which we have called proglottids.

There are many species of tapeworms, but all live as parasites in the intestinal tract of other animals, and nearly all require two hosts before their life-cycle is completed. And, somewhat as the liver flukes require a cold-blooded and a warm-blooded animal as their hosts, so the tapeworms usually require some herbivorous animal as a host for the larval stages, and an animal which eats the flesh of the herbivorous animal for the adult stages. We, therefore, have tapeworms using pig and man, cow and man, fish and man, mealworm and rat, fleas and dog, rabbit and wolf, etc., as the two hosts.

An adult tapeworm in the intestine of man will continually develop new proglottids which pass out of the body and shed the eggs upon the ground. Each proglottid may produce thousands of eggs. If these eggs then come in contact with grass, weeds, hay, or any vegetation which cattle or hogs eat, they hatch in the intestine of the animal eating such vegetation. In the case of the pork tapeworm, each egg will develop

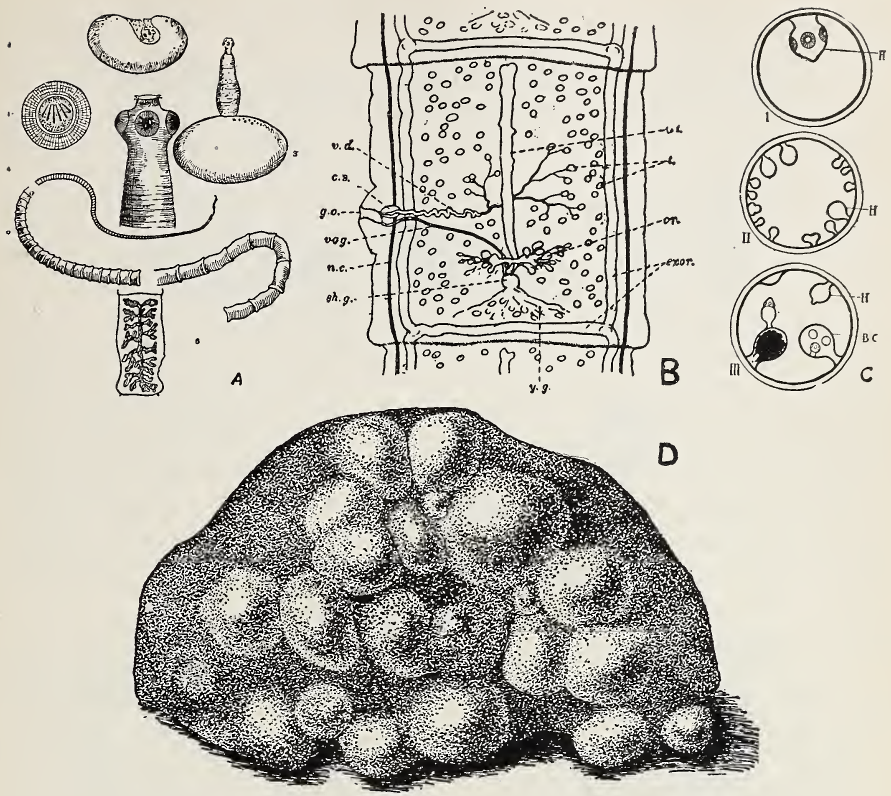


Fig. 183. Tapeworms.

A. The Life-History of *Tænia solium.* 1, six-hooked embryo in egg-case; 2, proscolex or bladder-worm stage, with invaginated head; 3, bladder-worm with evaginated head; 4, enlarged head of adult, showing suckers and hooks; 5, general view of the tapeworm, from small head and thin neck to the ripe joints; 6, a ripe joint or proglottis with branched uterus; all other organs are now lost.

B. A proglottis of *Tænia solium* with the reproductive organs at the stage of complete development. *cs.,* Cirrus sac; *excr.,* excretory canals; *g.o.,* genital opening; *n.c.,* nerve cord; *ov.,* ovary; *sh.g.,* shell gland; *t.,* testes; *v.d.,* vas deferens; *ut.,* uterus; *vag.,* vagina; *y-g.,* yolk gland.

C. Diagrams of Bladder-Worms. I. The Ordinary Cysticercus type, with one head. II. The Cœnurus type, with many heads. III. The Echinococcus type, with many heads, and with blood capsules producing many heads.

D. Portion of hog's liver infested with echinococcus bladder-worm. (A, after Leuckart; B and C, after Borradaile; D, after Stiles.)

a little six-hooked embryo which leaves the egg and bores its way into the hog's body. It comes to rest either in the liver or muscle tissue.

In about three months a bladder-worm known as a **cysticercus** has developed, and if flesh containing these bladder worms is eaten by man, he is in turn infected.

The cysticercus is really a tiny bladder-like sac with a scolex pushed in on one side. When this gets into man's intestine, the scolex is pushed outward so that it can fasten its hooks into its new host's intestine. It is now ready to bud off proglottids again.

At least one per cent of all cattle slaughtered in this country have tapeworms. Certain species are also found in pork. All meat should therefore, be well cooked before eating.

The structure of the tapeworm is quite similar to **Planaria**, the flatworm which served as our introduction to this phylum.

It is well, however, to obtain a good description of the way tapeworms reproduce, as it is due to their reproduction that infection takes place. The mature proglottid is almost entirely filled with reproductive organs. From the spherical testes (which are scattered throughout the entire proglottid) the sperm cells are carried through the vas deferens, after being gathered into fine tubules, and pass to the genital pore.

Eggs arise in the two-lobed ovary, and pass into the oviduct. Yolk from the yolk-gland then enters the oviduct and surrounds the eggs. After this, a shell is provided for the egg by the secretions from the shell-gland, and the eggs pass into the uterus. By this time the eggs have been fertilized and pass into the vagina. As the proglottid grows older, the uterus becomes extended with eggs and even sends off uterine branches likewise filled with eggs, while the rest of the reproductive organs are absorbed. The proglottid is then said to be ripe. When ripening occurs, the proglottid is very likely to break off and be thrown out with the faeces.

Cestode Infections.

There are four principal types of cestode worms (Fig. 184) which infect the human being. These are:

Taenia saginata or **mediocanellata,**
Taenia solium,
Bothriocephalus latus,
Taenia echinococcus.

Each of these requires an intermediate host for the development of the larval forms. The eating of the flesh of the intermediate host releases the larval forms, and the mature worm forms in the human host.

Taenia saginata (the **common beef-tapeworm**) is common in the small intestine of man in America. As the segments (which are loaded with eggs) ripen, they are discharged. The eggs are taken up with the food of the ox. Then the embryo pierces the intestinal wall with the four sucking discs on the worm's head. (There are no hooks in **T. saginata.**) As it bores its way through into the blood-stream, it is carried by the blood-stream throughout the entire system. Finally, the worm comes to rest in various muscles and develops into a **cystic larval form.** It is at this point that man becomes infected if raw beef is eaten which contains these larvae.

Taenia solium has less uterine pouches filled with eggs than **Taenia saginata.** These eggs are ingested by pigs. This type of tapeworm is rare in the human intestine in the United States, although it does occur. The process of development is quite like that of **Taenia**

saginata. The cystic larvae of **Taenia solium** are called **Cysticercus cellulosae.**

Bothriocephalus Latus is found in many types of fish, such as salmon, trout, perch, etc., and, if this is ingested by man, it passes through

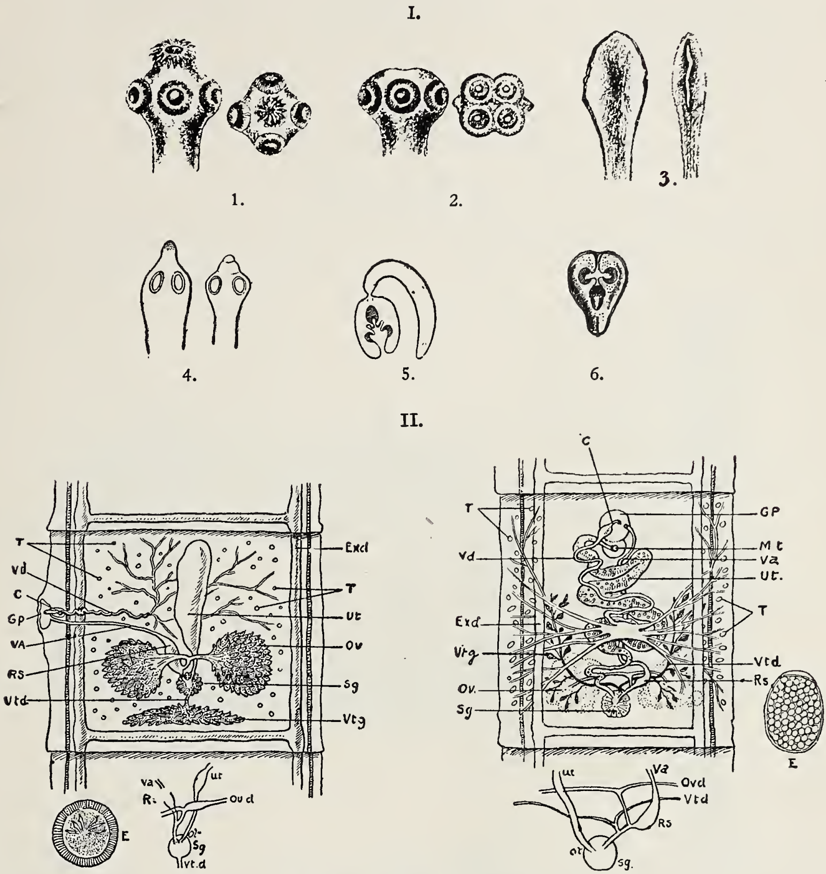


Fig. 184. Types of Cestoda.

I. Heads of 1, *Taenia Solium;* 2, *T. Saginata;* 3, *Dibothriocephalus latus;* 4, *Dipylidium caninum,* this latter showing rostrum both evaginated and invaginated; 5, immature and 6, mature cysticercoid. (From various authors.)
II. Diagram of the anatomy of Tapeworms. 1, *Taenia saginata;* 2, *Dibothriocephalus latus. T,* testes; *Vd.,* vas deferens; *C.,* cirrus; *Gp.,* genital pore; *Va.,* vagina; *Rs.,* receptaculum seminis; *Vtg.,* vitelline glands; *Vtd.,* vitelline duct; *Sg.,* shell gland; *Ov.,* ovaries; *Ovd.,* Oviduct; *Ut.,* uterus; *Ot.,* ootype; *Exd.,* excretory duct; *Mt.,* metraterm. (After Rivas.)

the various stages already mentioned and produces considerable anaemia. The genital openings are on the face of each segment in **Bothriocephalus latus** instead of at the edges as in **Taenia.**

Taenia èchinococcus differs from the three forms just mentioned in that man is the intermediate host and the dog the true host.

It also differs in size from those mentioned. Tapeworms in the human being may reach a length of **thirty** to **forty feet**, but **Taenia echinococcus** is only three mm. to six mm. in length. In cold countries where men and dogs live in the same room and where dogs lick their master's faces, eggs are transmitted to the human digestive tract, although intermediate hosts other than man are possible.

The developing cyst in the instance of the small worm is very large, and there is a closely allied form known as **Taenia multilocularis** which often is present with **Taenia echinococcus**, and when this is the case, a great mass of ramifying spongy tissue, full of small cavities, forms. If these cysts grow in the brain, the sheer pressure of the cysts cause injury and then, too, if the first cyst ruptures, it pours out poisons into the system, as well as again spreading new larvae which form secondary cysts.

The egg, when in the human intestine, hatches and bores through the intesinal wall and is swept along by the blood-stream to its lodging place. A thin, pearl-colored covering then surrounds it and about this the tissues of the host react so as to form a capsule. A liquid is formed in the thin membrane while buds grow out of the membrane. These buds are finally recognizable as the heads of new worms. The heads turn inside out, causing the hooks to face inward. This makes it possible for the worm to be swallowed by dogs and pigs. Then the head turns back again to make use of its hooks and suckers. If no intermediate host is found, the worms may die, but in such a case a large cyst filled with a mortar-like white material remains. Following is a summary of all the important **tapeworms and their hosts**:

Name	Final Host	Intermediate Host
Taenia solium	Man	Hog (in liver, muscles, brain, and eye).
Taenia saginata	Man	Ox and giraffe (in muscles).
Taenia elliptica		
Taenia cucumerina ...... (Both of these are also called **Dipylidium caninum**	Dog and cat mostly, but also man.....	In body-cavity of dog, fleas and lice.
Taenia flavo-punctata.... **(Hymenolepsis diminuta)**	Common in rats..... Twelve cases known in man.	Moths and beetles.
Taenia nana .... **(Hymenolepsis nana)**....	Common in Italy and known in America.	
Taenia confusa	A few cases in Man.	

Dibothriocephalus latus..	Man and Dog...... Common in Finland and regions where fish is a common food.	In peritoneum and muscles of pike, perch, and trout.
Drepanidotaenia setigera.	Goose	Water-flea and Cyclops brevicaudatus.

THE THREADWORMS

NEMATODA

The nematodes are the threadworms, or round worms, which make up the phylum **Nemathelminthes.**

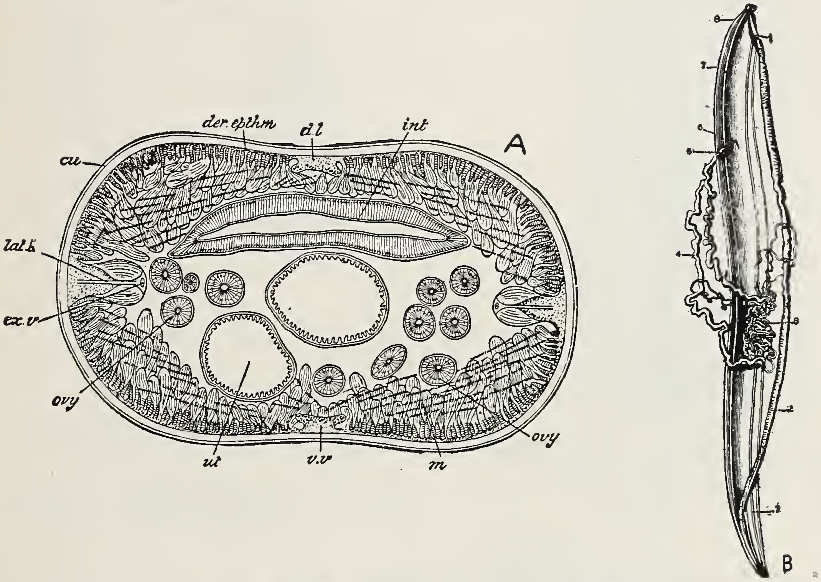


Fig. 185. A Cross Section, *Ascaris Lumbricoides.*

A, Transverse section. *cu.*, cuticle; *dl.*, dorsal line; *der.epthm.*, epidermis; *ex.v.*, excretory tube; *int.*, intestine; *lat. l.*, lateral line; *m.*, muscular layer; *ovy.*, ovary; *ut.*, uterus; *v.v.*, ventral line.
B. A female cut open to show internal structures. 1, pharynx; 2, intestine; 3, ovary; 4, uterus; 5, vagina; 6, genital pore; 7, excretory tube; 8, excretory pore. (A, after Vogt and Yung; B, after Shipley and MacBride.)

This phylum is likely to prove confusing to students as there are various systematists who classify threadworms under different phyla and under groups which they call "**uncertain.**"

Nematodes form the single class of **Nemathelminthes**, and the two best known forms used in the laboratory are **Ascaris lumbricoides** (Figs. 185 and 186), a parasitic worm found in the digestive tract of pigs, horses, and man, belonging to the family **Ascaridae**; and **Trichinella spiralis**

(Fig. 187), of the family **Trichinellidae**, which causes a very dangerous disease called **trichinosis** in rats, pigs, and man.

The female **Ascaris** is the larger of the sexes; in fact, it may grow to a length of from five to eleven inches and a quarter of an inch in diameter. The body is of a light brown color, with a narrow white stripe along the dorsal and ventral surface, and a broader white line

Fig. 186. Tuberculous Cavity in Oesophageal Wall of Man Containing an *Ascaris Lumbricoides*. (From a photograph lent the author by Dr. E. L. Miloslavich.)

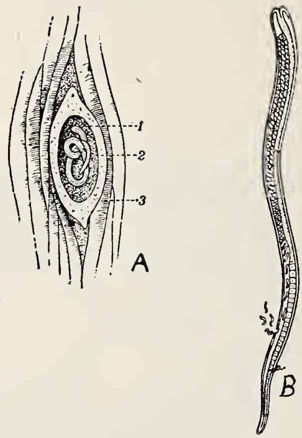


Fig. 187. *Trichinella Spiralis.*

A. Encysted Trichina Embryo.
B. Adult female from Intestinal wall. 1, parasite; 2, membrane of cyst; 3, muscle-fiber of pig. (After Leuckart.)

lying on each side of the dorsal and ventral stripe.

The mouth-opening (which is surrounded by one dorsal and two ventral lips) lies at the anterior end of the animal. The anal opening lies at the posterior end. The tail-end of the female is straight, while in the male it is slightly bent. In the male also there are **penial setae**, which extend through the anal opening and which are used for copulation.

The Digestive System.

The digestive system is very simple, consisting of a mere straight tube into which the already digested food of the host enters. A definite coelom may also be seen. The more anterior portion of the digestive tube is known as the **pharynx**. This is muscular, so that by contraction and expansion it can draw the host's food into itself. At the posterior end of the digestive tube the intestine becomes smaller. This is the **rectum**, which empties through the anal opening.

The Excretory System.

This system consists of two longitudinal canals, one located in each lateral line. These open through a single pore near the anterior end of the ventral body-wall.

The Nervous System.

A definite ring of nervous tissue surrounds the pharynx. From this ring a dorsal and a ventral nerve cord are given off, as well as a number of fine nerve strands and connections.

The Reproductive System.

In the male there is but a single testis, which is coiled and thread-like. The sperm cells pass from this through a **vas deferens** to a **seminal vesicle** and from here through the ejaculatory duct to the rectum.

In the female the reproductive system is Y shaped, the two arms of the Y being the coiled ovaries which are continuous with the uterus. It is the two uteri which unite in the stem of the Y to form a muscular tube, the **vagina**, which opens to the outside of the body by a **genital aperture**.

The egg is fertilized in the uterus, after which a chitinous shell surrounds it, and the egg is then thrown out through the genital pore. It is this chitinous shell which prevents the egg from being digested in the intestine of the host where it must necessarily fall when laid.

As nematodes are triploblastic animals with three definite germ layers, these animals also have a **coelom.** Consequently, the body of these worms must be thought of as a **tube within a tube,** with the reproductive system lying between the digestive tract and the body wall—that is, within the coelom.

However, the coelom is quite different in worms from what it is in higher animals. In the higher forms, the coelom is **a cavity between the two layers of mesoderm.** The excretory organs open into it and from its walls the reproductive cells originate. In **Ascaris** the coelom has only the mesoderm of the body wall as a lining. There is no mesodermal lining surrounding the intestines. Then, too, the excretory organs open directly to the outside through the excretory pore, and the reproductive cells do not originate from the epithelium of the coelom. Notwithstanding this difference, the space between the intestinal tract and the body wall is called coelom in worms.

Nematode Infections (Figs. 185, 186, 187, 188).

Ascaris lumbricoides is found chiefly in children. The female is from seven to twelve inches in length, and the male from four to eight inches. The worm is pointed at both ends and of a yellowish-brown or

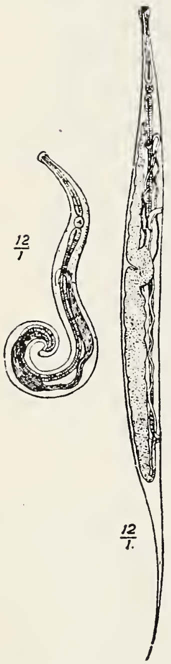


Fig. 188.
Oxyuris Vermicularis
The male is on the left, the female on the right.
(After Claus.)

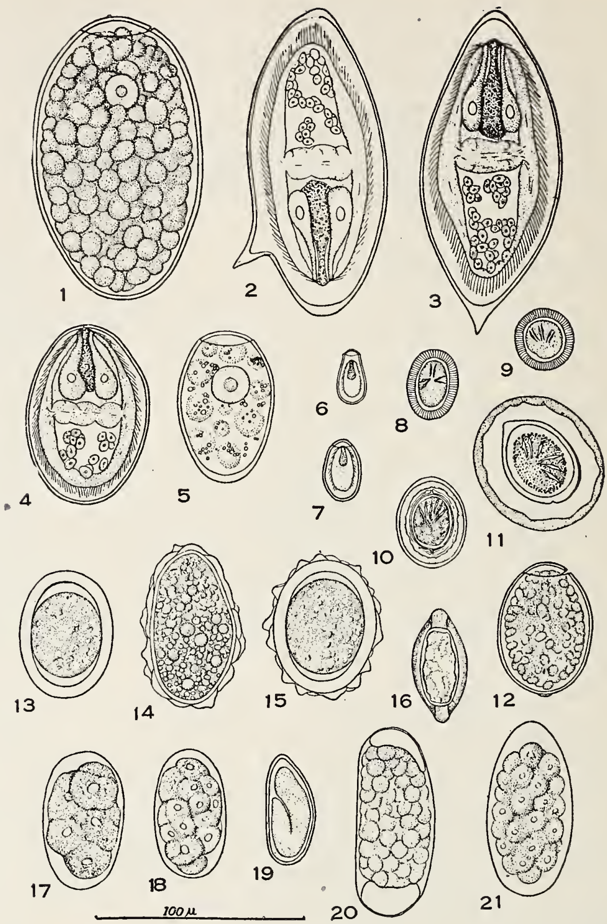


Fig. 189. Eggs of the More Important Worms Which Are Parasitic to Man.

As all are of the same magnification, a comparison of the relative sizes is possible.

1, *Fasciolopsis buskii;* 2, *Schistosoma mansoni;* 3, *Schistosoma haematobium;* 4, *Schistosoma japonicum;* 5, *Paragonimus westermanii;* 6, *Clonorchis sinensis;* 7, *Metagonimus yokogawai;* 8, *Taenia saginata;* 9, *Taenia solium;* 10, *Hymenolepsis nana;* 11, *Hymenolepsis diminuta;* 12, *Diphyllobothrium latum (Dibothriocephalus latus);* 13, *Ascaris lumbricoides* (egg without outer coating); 14, *Ascaris lumbricoides* (abnormal egg); 15, *Ascaris lumbricoides;* 16, *Trichuris trichiura,* 17 and 18, *Hookworm eggs;* 19, *Enterobius vermicularis oxyuris vermicularis;* 20, *Oxyuris incognita;* 21, *Trichostrongylus orientalis.* (After Hegner and Cort's "Diagnosis of Protozoa and Worms Parasitic to Man." Bull. Johns Hopkins University School of Hygiene and Public Health.)

slightly reddish color. There is no intermediate host. The animal occupies the upper portion of the small intestine. Usually one or two are found in a single location, although sometimes vast numbers of them may be found. The worm may pass to the stomach and be vomited forth, or it may crawl up the oesophagus and then pass into the larynx and asphyxiate the patient. In fact, it may enter any ducts or tubes in the body.

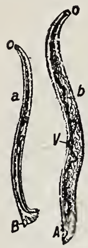


Fig. 190.
The Hookworm.
a., male; *b.*, female; *o.*, mouth; *V.*, opening for discharge of eggs. (After Leuckart.)

Oxyuris vermicularis (commonly called **pin-worms** or **thread-worms**), (Fig. 188), are parasites of the rectum and colon. The male is about 4 mm. long and the female about 10 mm. The parasites migrate and come close to the surface during the night, thus causing accentuated irritation and itching about the rectum and genital organs. Many eggs are found in the faeces of infected children. It is essential that the distinguishing and diagnostic difference between **oxyuris eggs** and **trichocephalus** eggs be known. Both types are quite alike except that **trichocephalus** eggs have a button-like lighter area (Fig. 189, 16). Re-infection must be guarded against. These worms often find their way into the appendix of children where they drill into the mucous membrane and cause appendicitis. **Trichina** (Fig. 187), (also called **Trichinella spiralis**), lives in the small intestine when adult. The disease **trichiniasis** is caused by the embryos after they pass from the intestines to the voluntary muscles where they encapsulate themselves as larvae.

The female is 3 to 4 mm. long and the male 1.5 mm. There are two tiny projections from the posterior end of the worm. The larvae, when encased in the muscle, are about 1 mm. long. **Trichina** has a pointed head and a somewhat rounded tail. The parasites are ingested by man when eating inadequately cooked pork. Each worm may produce as high as 10,000 young, which are either placed directly into the lymphatics by the female or burrow through the intestinal wall. They then encyst in the muscle tissue. Pigs acquire the disease by eating offal or infected rats.

Twenty-six different kinds of animals have been found to harbor trichinae, and as many as 15,000 of these parasites have been found in one gram of muscle.

It may take about six weeks for complete encapsulation, but once encapsulated, they may remain alive in the muscle for twenty or twenty-five years.

Pigs may be literally "filled" with these parasites, although they may show no external sign of infection. The result is what is known as "measly" pork. Many countries now insist on pork inspection to prevent a spread of infection.

The patient usually suffers with a fever, anaemia, muscle pains **(myositis)**, which are often mistaken for rheumatism, and intestinal disturbances (gastro-enteritis).

Ankylostoma duodenale in the old world, and **Necator americanus** in this country are the **Hook-worms** (Fig. 190). The disease caused by hook-worm is variously known as ankylostomiasis, uncinariasis,

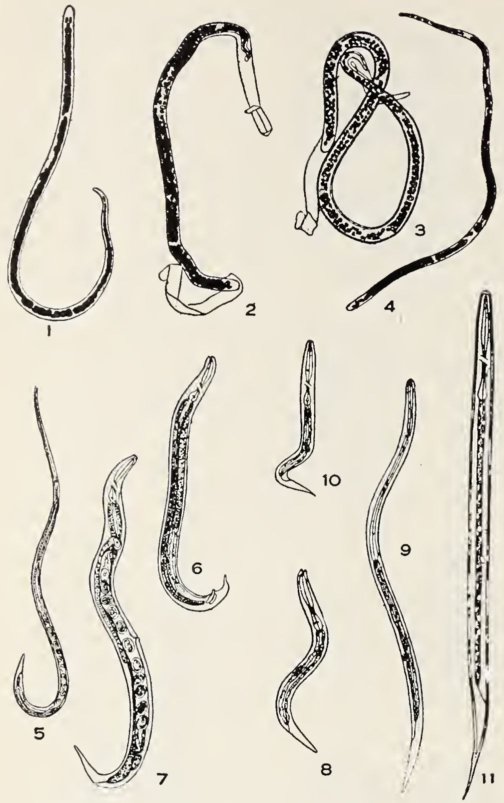


Fig. 191. Forms of Worms Parasitic to Man.

1. Larval stage of *Filaria ozzardi* (F. demarquayi).
2. Larval stage of *Loa loa (Microfilaria diurna).*
3. Larval stage of *Filaria bancrofti (Microfilaria nocturna.)*
4. Larval stage of *Acanthocheilonema perstans (Microfilaria perstans).*
5. Adult parasite female of *Strongyloides stercoralis.*
6 ad 7. Adults, male and female, of the free-living generation of *Strongyloides stercolaris.*
8. Rhabditiform larva of *Strongyloides stercoralis,* just hatched from egg.
9. Filariform infective larva of *Strongyloides stercoralis.*
10. Rhabditiform larva of *Ancylostoma duodenale,* just hatched from the egg.
11. Filariform infective larva of *Ancylostoma duodenale.* (From Hegner and Cort's "Diagnosis of Protozoa and Worms Parasitic to Man;" 1-4, after Fulleborn; 5-11, after Looss.)

hook-worm disease, tropical or Egyptian chlorosis, and anaemia of bricklayers and tunnel-workers.

The old-world animal is small and cylindrical, the male being about 10 mm. in length and the female from 10 to 18 mm. There are chitinous plates about the mouth and there are two pairs of sharp, hook-shaped teeth with which the mucosa of the intestine is pierced. On the male there is a prominent caudal, umbrella-like expansion. The American species is slightly more slender, with a globular mouth and a different arrangement of teeth. The eggs of the American form are slightly larger than those of the European forms.

The larvae of the hook-worm develop in moist earth and dig their way through the soles of the feet of persons who go barefooted. Once in the blood-stream, they are carried along by it to the heart, thence to the lungs. Many lodge in the windpipe from whence they are swallowed, thus reaching the stomach and intestines. The larval forms here attach themselves to the intestinal walls and feed on the blood of their host. But as they puncture the intestinal wall, they exude a small amount of poison which prevents the host's blood from coagulating. There is thus a constant loss of tiny droplets of blood and the patient naturally becomes anaemic. Not only do persons infected with hook-worm suffer from such loss of blood, but the parasites injure the lungs in passing through them, and thus make tuberculosis infections easy.

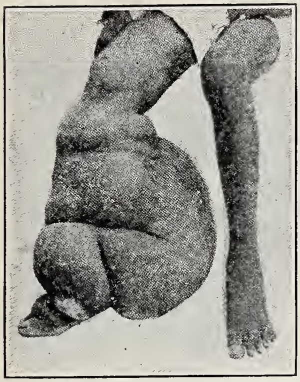


Fig. 192. Elephantiasis in Man. (From "New Sydenham Society's Atlas.")

The writer has been told by a worker in the medical corps of the army that more than 75 per cent of the examined southern negroes showed hookworm infection.

It is of great importance to dispose of all human faeces in rural districts, in mines, brick-yards, etc., so that the soil will not become polluted. This will at the same time kill the eggs and thus prevent their hatching. Strong sunlight also seems to be quite effective in killing such eggs.

The family **Filariidae** is also important from a pathological point of view.

Filaria bancrofti (Fig. 191) is a parasite which lives in human blood. It is interesting to know that this parasite lives in the lungs and larger arteries throughout the day and in the blood vessels in the skin at night. Mosquitoes, which are active at night, suck the blood of infected persons and thus carry the infection. In fact, it was the knowledge of this peculiarity of Filaria bancrofti which led to the discovery of the malarial parasite's life cycle.

After the larvae have developed in the mosquito's body, the organisms are placed in another person by the mosquito. They enter the lymphatics and cause serious difficulties, probably by blocking the lymph passage. If there is such a blocking, **elephantiasis results.** This is a practically incurable disease in which the limbs, or other portions of the body, swell to an enormous size, although producing little or no pain. (Fig. 192.) In certain portions of the South Sea Islands, almost a third of the population is affected.

Medical men speak of **Filaria diurna** and **Filaria perstans.** The first of these differs from **F. bancrofti** in not having granules in the axis of the body, and the second in having embryos smaller (namely, about 200 microns) than the preceding. Only the embryos have been seen. The embryos of **F. bancrofti** are about 270 to 340 microns in length. The adult is about 83 mm. long, and the female some 155 mm. The tail in the male has two spiral turns. The female produces vast numbers of young which enter the blood stream through the lymphatics. Each embryo is inclosed in a tiny shell, about one ninetieth of an inch in length. They pass through the capillaries quite readily. They can be seen in a blooddrop under the microscope. As many as 2,100 embryos have been seen in 1 cc. of blood.

Dracunculus medinensis is a peculiar worm, the female of which is about a yard long. It is probably taken in with food. It makes its way downward, and, when arriving at the ankle, usually pushes its head through the skin, causing an abscess. As the eggs are then deposited, it

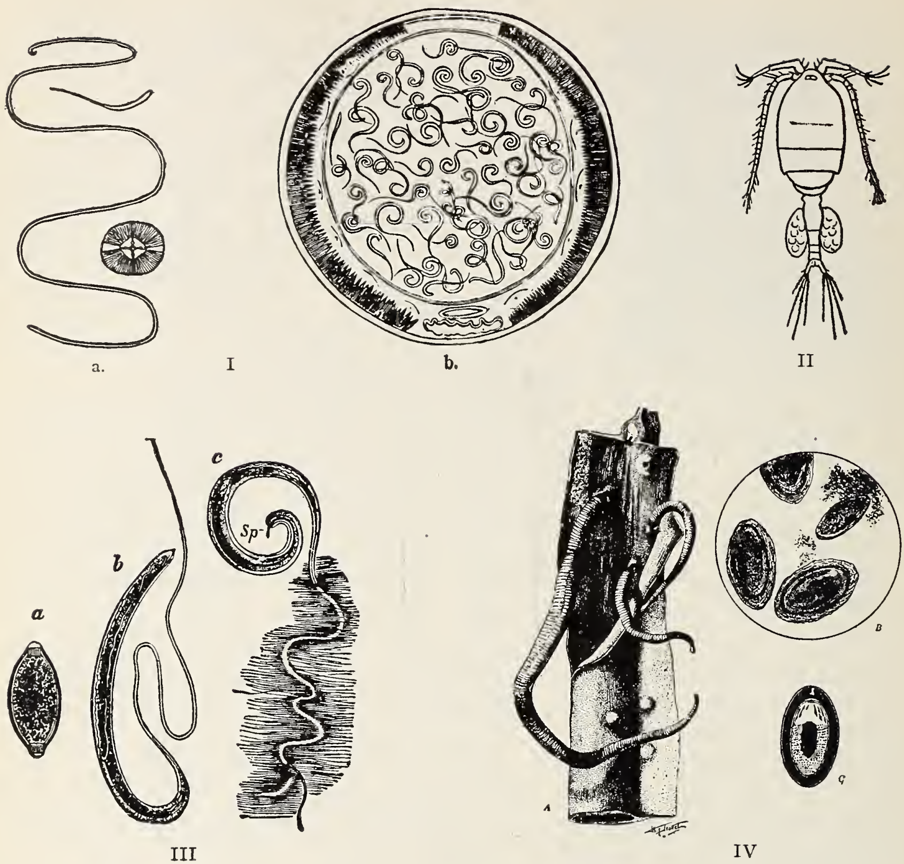


Fig. 193. Other Nematode Parasites.

I. *a., Dracunculus (filaria) medinensis* (female), showing mouth and embryo. *b.*, Transverse section through adult female of I, *a*, showing many embryos in the uterus.

II. *Cyclops.* This animal is the intermediate host of *Dracunculus.*

III. *Trichocephalus dispar* (also called *Trichuris trichiura)* of the Family *Trichinellidae. a.*, egg; *b.*, female; *c.*, male attached to the intestine, showing the long, slender, cephalic end buried in the submucosa; *sp.*, spicule.

IV. *Gigantorhynchus gigas,* of the Class *Acanthocephala,* and Family *Echinorhynchidae. A.*, two males and one female adult attached to the mucosa of the intestine; *B.*, eggs as seen in preparation; *C.*, eggs as found in feces. (I, after Bastian and Leuckart; II, after Riley and Johannsen; III, after Leuckart; IV, after Brumpt and Perrier.)

leaves the infected person of its own accord. Few of these have been found in America.

Trichocephalus dispar (Fig. 193), or **whip-worm**, is found in the caecum and large intestine of man. It is 4 to 5 cm. in length, the male being a trifle shorter than the female. The parasite is remarkable in that there is a great differentiation between the two ends of the body. The anterior end, which forms about three-fifths of the body, is very thin and hair-like, while the posterior portion is thick. In the female, the posterior end is conical and pointed; in the male, it is blunter and rolled like a spring. The eggs are lemon-shaped, 0.05 mm. in length. Each has a button-like projection. There may be as many as a thousand parasites in one person. The parasite produces no known symptoms in the patient, although patients who have been infected have become anaemic and suffered with diarrhoea.

Dicotophyme renale is a worm, the male of which is over a foot long and the female over three feet. These are seldom met with, but when present may destroy the entire kidney.

Anguillula aceti or (vinegar eel) has been found in the urine of man, although it is supposed to have been in the bottle in which the urine was collected.

Strongyloides intestinalis is found in the small intestines of man in the tropics. Three per cent of the medical patients of the Isthmus of Panama were found to be infected, and 20 to 30 per cent of the insane division.

Acanthocephalus (thorn-headed) is also called **Gigantorhynchus** or **Echinorhynchus.** These are quite common in the intestine of the hog, where they attach themselves by means of a protrusible proboscis covered with hooks. In the old world the larva develops in cockroach grubs, while in America the larva develops in the June bug.

The **Acanthocephalia** are distinguished from the **Nematodes** and the **Nematomorpha** by the presence of a proboscis and the absence of an alimentary canal.

INTERMEDIATE AND UNCERTAIN FORMS

In addition to the rather definite groups of worms mentioned in this book, there are also various forms of uncertain position.

The term **Mesozoa** (Fig. 194)—(Gr. **mesos,** middle—**zoon,** animal)—is often used as a general grouping for the three following families of parasites: (1) **Dicyemidae,** (2) **Orthonectidae,** (3) **Heterocyemidae.**

They are called **Mesozoa** because they are regarded as intermediate forms between the protozoa and the metazoa. They are closely allied to the flat worms.

The Nemertinae (Gr. **nemertes,** true), are usually placed with the flat worms. They may reach a length of ninety feet and are mostly marine, though a few live in fresh water and in moist earth.

Cerebratulus ( ), and **Micrura** ( ), (Fig. 195), are the usual examples of marine **Nemertinae.** Other forms are not common. **Malacobdella** ( ) is parasitic in some mollusks.

The Nemertinae are considered **the lowest form of animal life** in which the **blood-vascular system appears.** There is a definite mesoderm and a nervous and an excretory system quite like those in flatworms, but they all have a long proboscis just above the digestive tract which lies within a sheath. This can be everted. The body is covered with

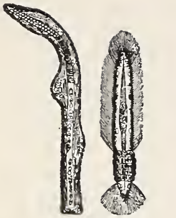
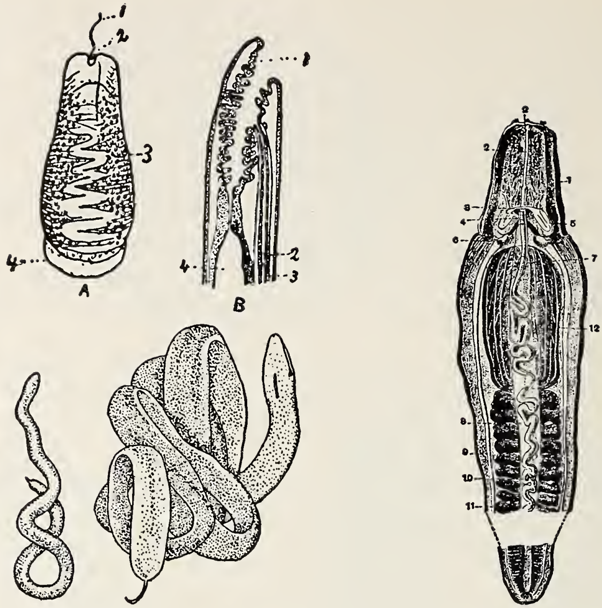


Fig. 194.
A. A Mesozoon, *Dicyema Paradoxum.* (From Parker and Haswell, after Kölliker.)
B. A Mesozoon, *Rhopalura giardii,* male. (From Sedgwick, After v. Beneden.)



C D Fig. 195. E

A. *Malacobdella grossa* (Verrill), entire worm. 1, proboscis; 2, mouth; 3, intestine; 4, sucker.
B. Section through forward end. 1, mouth; 2, proboscis; 3, proboscis sheath.
C. *Micrura leidy,* (Verrill.)
D. *Cerebratulus lacteus* (Verrill). (From Pratt's "Manual" by permission of A. C. McClurg & Co.)

E. *Cerebratulus fuscus,* a Nemertine. 1, cephalic slits; 2, opening leading into retracted proboscis; 3, dorsal commissure of nervous system; 4, ventral commissure; 5, brain; 6, posterior lobe of brain; 7, mouth; 8, proboscis; 9, lateral vessel; 10, proboscis; 11, pouches of alimentary canal; 12, stomach. (From Shipley and MacBride, after Bürger.)

cilia. These animals feed on other animals both dead and alive. They usually live in burrows of mud and sand, though **Cerebratulus** is free-swimming.

A peculiar larval stage known as the **Pilidium** (Fig. 198 D), resembling a helmet with cilia and a long tuft at the apex, is a distinguishing feature of the development of **Nemertinae.** Ectodermal invaginations surround the alimentary tract of the **Pilidium.** This invaginated portion escapes from the larval form and becomes an adult.

The **Nematomorpha** (Gr. **nema,** thread—**morphe,** form), is made up of the single family **Gordiidae** (Fig. 196). These are the common **horse-hair snakes.** Various authors classify them under the order of **Nematoda,** while others classify them under the **Phylum Nemathelminthes.** There are two genera: **Gordius,** which lives in fresh water, and **Nectonema,** a marine form. The internal anatomy is somewhat different from the **Nematodes,** as there is a distinct **epithelium** lining the body cavity and **no lateral lines.** There is also a **pharyngeal nerve-ring,** and a **single**

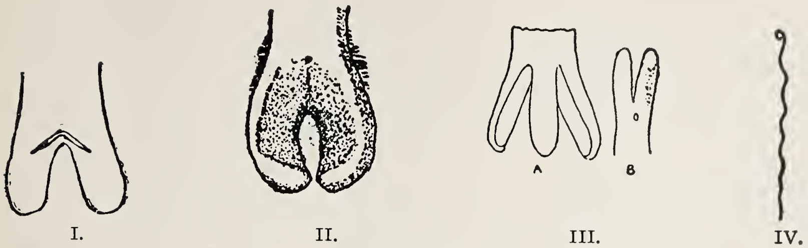
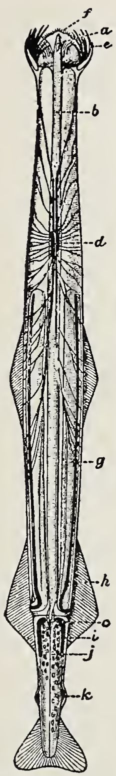
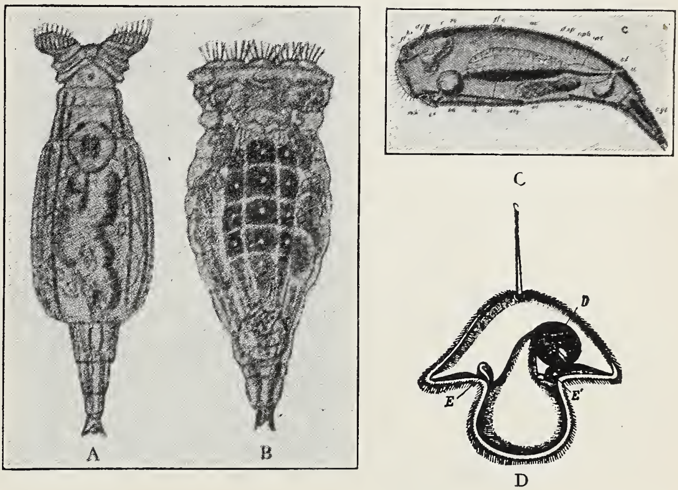


Fig. 196.

I. *Gordius aquaticus;* hinder end of male.
II. *Gordius lineatus;* hinder end of male.
III. *Paragordius varius;* A, hinder end of female; B, of male.
IV. *Nectonema agile;* (From Pratt's "Manual" by permission of A. C. McClurg & Co.)





A. B. Two species of Rotifera. A, Philodina. B, Hydatina. (From Parker and Haswell, after Hudson and Gosse.)

C. Diagram showing the anatomy of a Rotifer. *a,* anus; *br,* brain; c^1, preoral, and c^2, postoral circlet of cilia; *c.gl,* cement gland; *cl,* cloaca; *d.ep,* dermic epithelium; *d.f,* dorsal feeler; *e,* eye; *fl.c,* flame-cells; *int,* intestine; *m,* muscles; *mth,* mouth; *nph,* nephridial tube; *ov,* ovum; *ovd,* oviduct; *ovy,* germarium; *ph,* pharynx; *st,* stomach; *vt,* vitellarium. (From Parker and Haswell.)

D. *Philidium* larva of a Nemertine. *D,* alimentary canal; *E, E',* the two pairs of ectodermal invaginations. (From Sedgwick, after Metschnikoff.)

Fig. 197.
The arrowworm, *Sagitta hexaptera* (of the group Chaetognatha), ventral view. a, mouth; b, intestine; c, anus; d, ventral ganglion; e, movable bristles on the head; f, spines on the head; g, ovary; h, oviduct; i, vas deferens; j, testis; k, seminal vesicle. (After Hertwig.)

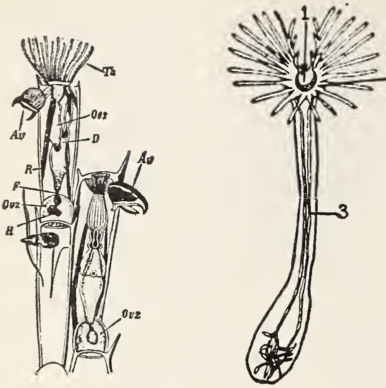


Fig. 199.

A. *Bugula avicularia*, a Bryozoon. *Av*, avicularia; *D*, alimentary canal; *F*, funiculus; *Oes*, œsophagus; *Ovz*, ovicells; *R*, retractor muscle; *Te*, tentacular crown. (From Sedgwick, after V. Nordmann.)

B. *Phoronis architecta*. Young individual with about 30 tentacles. 1, epistome; 2, lophophore; 3, digestive tract. (From Pratt's "Manual" by permission of A. C. McClurg & Co.)

ventral nerve-cord, while the ovaries discharge the eggs **into the body-cavity.** Then, too, the larvae of **Gordious** usually enter immature stages of aquatic insects. These insect larval-forms are then devoured by other animals, and it is in the intestines of the host where they develop until they finally escape into the water.

The **Acanthocephala** (Gr. **akantha,** spine—**kephale;** head) are the parasitic worms already mentioned above (Fig. 193), which may infect man. They fasten themselves to the intestinal wall of their host by means of a **protrusible proboscis** covered with hooks. In fact, it is the presence of the proboscis and a reproductive system as well as the absence of an alimentary system which distinguishes the **Acanthocephala** from the **Nematoda** and the **Nematomorpha.** There is an alternation of hosts during the developmental stages.

The **Chaetognatha** (Gr. **chaite,** horse-hair+**gnathos,** jaw) are marine forms swimming about near the surface of the water. The **arrow-worm** (Fig. 197) is the classic example. This is a member of the genus **Sagitta.** The **Chaetognatha** are quite often included under the **Phylum Nemathelminthes.**

The **Rotifera** or **Rotatoria** (Fig. 198), (Lat. **rota,** wheel-**fero,** I carry), are usually called the **wheel-animalcules.** They are very small and were formerly thought to belong to the **Infusoria.** Most of them live in fresh water. A few are parasitic. The sexes are separate. Summer and winter eggs are produced by the female. The former are thin-shelled and develop without fertilization **(parthenogenetically).** The larger eggs produce only females while the small eggs reproduce males. The winter eggs are fertilized, have thick shells, and all develop into females. The eggs of the most mollusks pass through a larval stage known as a **trochophore** ( ), which looks quite like the helmet-shaped larva described above. Now, **Rotifers** often resemble these **trochophores.** Consequently, it is thought by some zoologists that they must be closely related to the mollusks. Rotifers have a peculiar ability to secrete about themselves in times of drought a gelatinous envelope, which protects them for great lengths of time and thus prevents them from perishing.

The **Bryozoa** (Gr. **Bryon,** moss—**zoon,** animal) are **moss-animals**

(Fig. 199), which practically all live **a colonial life.** They look something like the hydroid form of **Obelia,** but their general structure is quite unlike **Obelia.** Most of them are marine animals, though there are a few types which inhabit fresh water. **Polypide** is the name given to the soft parts which lie within **a coelomic cavity** and which is surrounded by the **zoöecium** (body-wall).

The **lophophore** ( ) is the crown of ciliated tentacles surrounding the mouth. The **alimentary tract, retractor muscle,** and the **funiculus** (a strand of mesodermal-tissue attached to the stomach), are shown in Figure 199. There are **no circulatory or excretory organs.** The eggs develop in the **oöecium,** which is a modified portion of the body-wall.

Bugula is the usual laboratory example. Certain members of a colony develop jaws for protective purposes. Such jaw-possessing members are called **aviculariae.**

Bryozoa are divided into **Ectoprocta** in which the anus **opens outside** the lophophore, and a coelom is present as in **Bugula**; and **Entoprocta,** in which the anal opening lies **within the lophophore,** while the portion which should be a coelom is filled with mesodermal cells. Examples of this type are **Pedicellina** and **Urnatella.**

The **Phoronidea,** named after an ancient king, **Phoronis,** consists of the single genus **Phoronis.** The animals belonging to this group are worm-like and are enclosed **in membranous** tubes. They live in sand and are supposed to be related to the **Ectoprocta.**

The **Brachiopoda** (Gr. **brachion,** arm—**pous,** foot) are shelled marine animals (Fig. 200), but with the shell **on the dorsal and ventral portions** of the animal, instead of on the sides as with bi-valves. They are usually attached to some object by a **peduncle.** An excellent example is **Lingula,** a very old type, which has been found in some of the oldest geological strata, and which differs but little to-day from the oldest fossil-remains.

The **Brachiopoda** are not worm-like in any way, but have an uncertain position in classification, and so are included here.

The **Gephyrea** (Fig. 201), (Gr. **gephyra,** mound), often classified under the annelids, are now believed by zoologists to be unrelated to them, but there is even doubt that the various sub-groupings of **Gephyrea** themselves bear any very close relationship.

Three groups are usually mentioned:

(1) The **Echiuroidea,** in which the adult shows traces of segmentation, a **proboscis,** and a **pair of ventral-hooked-setae and terminal anus.** There is a larval trochophore stage. They ordinarily live in crevices of rocks.

(2) The **Sipunculoidea** are **unsegmented.** They possess **one pair of nephridia,** a **large coelom,** and an **anal opening on the dorsal surface, near the head-end.** They usually possess tentacles at the anterior end. They live in sand or bore their way into coral rock.

(3) The **Priapuloidea** are also **unsegmented,** having an anterior-

mouth surrounded by **chitinous teeth** and **the anal opening in the posterior region.** They live in mud and sand. The head-end usually projects above the surface of the mud in which they lie.

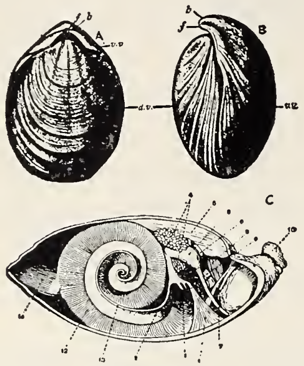


Fig. 200.

Magellania flavescens (of the group Brachiopoda). A, dorsal aspect of shell. B, shell as seen from the left side. *b*, beak; *d.v.*, dorsal valve; *f*, foramen; *v.v.*, ventral valve. (From Weysse, after Davidson.)

Anatomy of a Brachiopod, *Waldheimia australis*. 1, mouth; 2, lophophore; 3, stomach; 4, liver tubes; 5, median ridge on shell; 6, heart; 7, intestine; 8, muscle from dorsal valve of shell to stalk; 9, opening of nephridium; 10, stalk; 11, body-wall; 12, tentacles; 13, coil of lip; 14, terminal tentacles. (From Shipley and MacBride.)

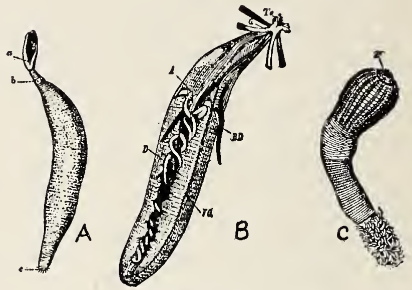


Fig. 201.

A. *Echiurus pallassi* (of the group Gephyrea). *a*, mouth at the end of the grooved proboscis; *b*, ventral hooks; *c*, anus. (From the Cambridge Natural History.)

B. *Sipunculus nudus* (of the group Gephyrea) laid open from the side. *A*, anus; *BD*, brown tubes (nephridia); *D*, intestine; *G*, brain; *Te*, tentacles; *VG*, ventral nerve-cord. (From Sedgwick, after Keferstein.)

C. *Priapulus candatus* (of the group Gephyrea). *a*, mouth surrounded by spines. (From the Cambridge Natural History.)

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CHAPTER XXI

THE ARTHROPODA

THE CRAYFISH

AS AN example of a gill-breathing arthropod, the crayfish has become the classic laboratory type, and this because, like the frog, it is already known to the student to some extent.

The phylum to which man and the frog belong— the **Vertebrate**— is in point of numbers much smaller than the phylum **Arthropoda**, to which the crayfish belongs—a group embracing more than three-fourths of all living animals.

The **Arthropoda** are usually divided into **branchiata**[1] (   ) —commonly called crustacea (   )—those animals possessing a hard **chitinous** (   ) **exoskeleton** and breathing **with gills**, practically all of which live in water; and **tracheata** (   ), consisting of those animals breathing through little tubules called tracheae. The tracheata include **grasshoppers, bees, wasps, ants, spiders**, and **insects** of all kinds. While 400,000 of the 600,000 known species of animals belong to the **Arthropoda**, the greatest sub-group of these is, in turn, the **insects**.

The crayfish is large enough to be studied profitably in the laboratory. All who have lived or spent any of their youth near ponds and rivers, know at least one or two species of crayfish. These they have found lying quietly under stones in running streams, and when such stones were lifted, the animal's **pincers** were threateningly brought forward to clasp the fingers of the supposed attacker. Then followed a darting backward until the animal again pushed itself under some sheltering object or was able to find some close corner in which its body could be pressed.

The exterior skeleton so prominent in the arthropoda, is in thorough contrast to that of the frog, whose supporting tissues are placed on the innermost portion of its body; yet it is not from this characteristic that the phylum is named, but from the fact that the animals belonging to this group have jointed legs. The word arthropoda **means jointed feet.**

The crayfish will be used in this book more as a type to introduce nomenclature and general arrangement of the phylum arthropoda than as a study of detail.

The entry into a more minute investigation of the phylum will come with a study of the grasshopper. The larger and more convenient size

[1]This classification into *Branchiata* and *Tracheata* lacks scientific foundation, but is convenient for the beginner and for the student of medicine. As an example of why this classification is not scientific, we may mention the fact that true spiders have no tracheae and yet are called Tracheates.

of the crayfish serves to show in gross much that is otherwise difficult to observe in the insects and lends itself well to an illustration of **serial homology** and the so-called **Savigny's law.** The crayfish has not been well studied, unless, after completing this chapter, these things are definitely known.

EXTERNAL APPEARANCE

The crayfish is found nearly everywhere in this country and Europe. In the eastern part of the United States **Cambarus affinis** ( ) is prevalent, while **Cambarus virilis** ( ) is more plentiful in the middle states, and the European specimen found most frequenly is **Astacus fluviatilis** ( ). There is little difference, however, in the external or internal makeup of the different species. It

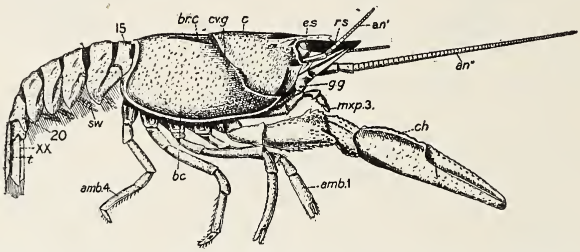


Fig. 202. The common Crayfish, *Astacus fluviatilis,* seen from the side.

abd. Abdomen. *amb.* 1. First walking leg. *amb.*. 4. Fourth walking leg. *an'.* First antenna or antennule. *an''.* Second antenna. *bc.* Branchiostegite. *br.c.* Branchiocardiac groove. *c.* Carpace. *ch.* Chela. *cv.g.* Cervical groove. *e.s.* Eye-stalks. *gg.* Opening of green gland. *mxp.* 3. Third maxillipede. *rs.* Rostrum. *sw.* Swimmerets. *t.* Telson. 15. First segment of abdomen. 20. Last segment of abdomen. xx. The last appendage. (After Shipley & MacBride.)

will be remembered that the segmentation of the frog is found in the spinal column. With the crayfish, segmentation can be observed externally, running from anterior to posterior end, though there is a peculiar condition of **fusing** of a number of the anterior segments (Fig. 202) which form the **cephalothorax** ( ).

As one may observe in the embryological study of the crayfish that each embryonic segment possesses a pair of appendages, it is but necessary to count the appendages in an adult arthropod in order to find how many segments have fused in any given region. This is known as **Savigny's Law.**

Beginning at the anterior end of the animal we find that the first segment has two pairs of long feelers, the longer ones being the **antennae** and the shorter the **antennules.**

Directly behind these there is a series of **modified appendages** (Figs. 202, 203). The larger pair are the **mandibles,** which cover the mouth itself. Two pair of tiny appendages—the **maxillae**—lie posterior to the mandible, while three pairs of appendages—the **maxillipeds**—posterior to the maxillae (really attached to the thorax) are so modified that they, too, belong to the mouth formation. The two pair of maxillae and the three pair of maxillipeds, together with the **mandible,** thus make **six pairs of jaws** altogether.

Back of these six pairs of jaws, a pair of pincers is attached to the thorax proper. These are known as **chelipeds** ( ), and behind the chelipeds are **four pair of walking legs.** By observing these legs it will be noticed that they are very much akin to the cheale proper in that each has a broad attachment where it meets the body, the

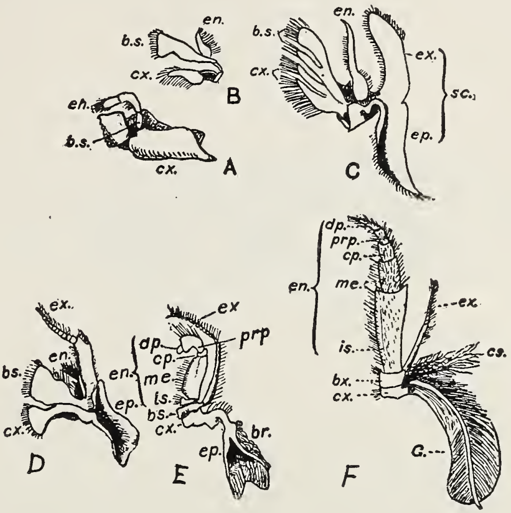


Fig. 203.

A. Mandible. B. First maxilla. C. Second maxilla. *bs.* Basipodite. *cx.* Coxopodite. *en.* Endopodite. *ep.* Epipodite. *ex.* Exopodite. *sc.* Scaphognathite.
D. and E. First and second Maxillipedes. *br.* Branchial filaments. *cp.* Carpopodite. *dp.* Dactylopodite. *is.* Ischiopodite. *me.* Meropodite. *prp.* Propodite portions of endopodite.
F. Third Maxillipede. *cs.* Coxopodite setæ.
G. Gill (=epipodite.) (After Latter.)

protopodite ( ), composed of two portions, a **coxopodite** ( ) and a **basipodite** ( ) which then join the pincer proper. These pincers consist of a solid immovable portion, the **exopodite** ( ) and a smaller movable and inner portion, the **endopodite** ( ).

It will be observed that the pincers are only enlarged walking legs.

The portion of the crayfish directly behind the cephalothorax, with the definite segmentation, is known as the **abdomen** and consists of six segments, beside the tail. The tail consists of a central portion called the **telson** ( ), and two pairs of leaf-like structures on each side called **uropods,** which assist in forming a broad wing-like tail and which, when the crayfish is frightened, can be bent rapidly forward, thus sending the animal's body backward from the position it occupied.

A typical segment of the abdomen (Fig. 204) consists of the upper portion called the **tergum** ( ), a ventral portion, the **sternum**, two **pleura** (the extended portions continuing ventrally behind the **sternum**), and two **epimera**, these latter forming the roof which extends from the pleura to the appendage.

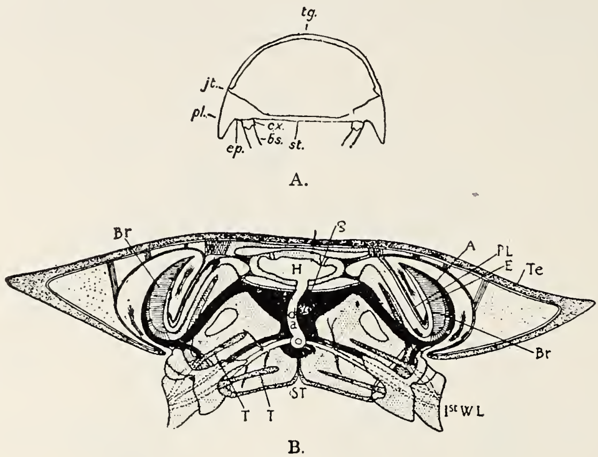


Fig. 204

A. Diagram of skeleton of an abdominal segment of *Astacus*. *bs*. Basipodite. *cx*. Coxopodite of swimmeret. *ep*. Epimeron. *jt*. Point of articulation with skeleton of adjacent segment. *pl*. Pleuron. *st*. Sternum. *tg*. Tergum. (After Latter.)
B. Section through cephalothorax of a crab. (After Pearson.) *H*., Heart; *Te*., extension of the tergum; *ST*., sternum; *PL*., pleuron; *T*., tendons; 1*st W*. *L*., insertion of first walking leg; *Br*., gill in gill-chamber; *g*., gut; *d.a*., descending artery; *A*., afferent branchial; *E*., efferent branchial.

There are thirteen segments in the **cephalothorax**. The eyes are not counted as appendages. A **cervical groove** forms the separating line between head and thorax. The entire **dorsal shield** of the cephalothorax is called the **carapace** ( ); the jointed end extending between the eyes is known as the **rostrum**, while the portion on the sides covering the gills are the **branchiostegites** ( ). The entire crayfish possesses twenty segments, counting telson and uropods as one.

Each pair of the appendages is slightly different in appearance from any other pair, though there is much similarity between them. The three distinguishing types of crayfish appendages are known as (1) **foliaceous** ( ), (second maxilla); (2) **biramous** ( ), (swimmerettes); (3) **uniramous** ( ), (walking legs).

The female has an opening at the base of the third walking leg through which eggs are extruded. She also possesses a single opening in the midline through which sperm may be inserted. Immediately behind the left walking leg, on the first abdominal segment, a peculiar **atrophied** ( ) **pair** of appendages is found.

In the male, however, these appendages on the first and second abdominal segment are wide, and the left walking leg possesses a small opening through which the sperm are ejected. In the male the first pair of swimmerettes is also transformed into "copulating organs." The anal opening is found on the ventral surface in the midline of the telson.

SERIAL HOMOLOGIES AND ADAPTATIONS

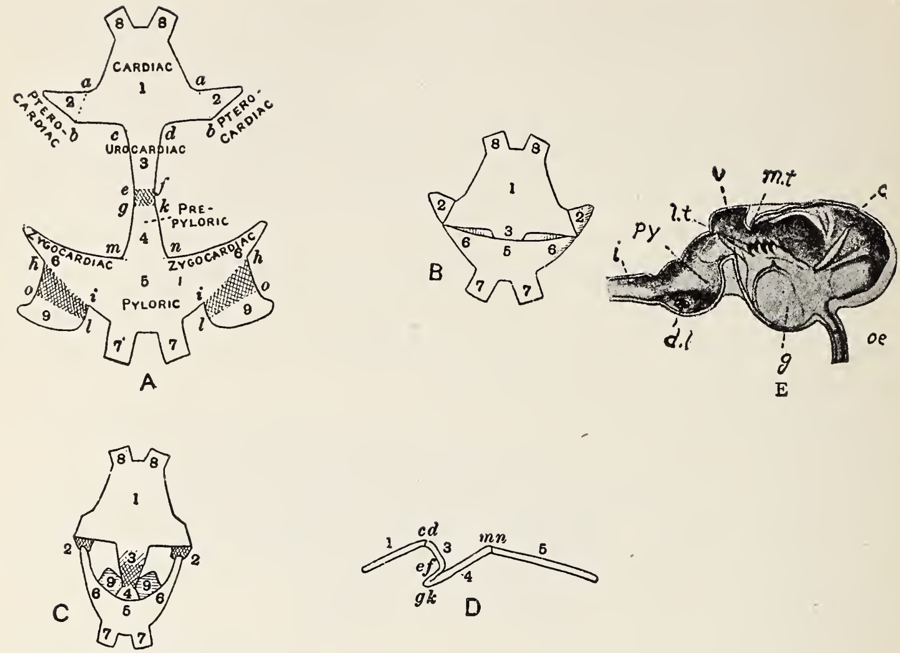
When two parts of an organism develop alike as to structure, for example the femur in the thigh and the humerus in the upper arm, we call such bones or parts **homologues** ( ).

And when two parts function similarly, regardless of whether they are alike structurally, we call such organs or parts **analogues** ( ). While if any organ or part of an organ changes, due to a change of environment so as to better or benefit an organism, we call such change an **adaptation.** In the crayfish there is what is called a **serial homology.**

This type of "homology" is characteristic of the group of the **higher crustacea** known as the sub-class **Malacostraca** ( ), and this group well illustrates how a single plan of structure may run through a series of forms of the utmost **diversity in appearance,** and how parts essentially alike may be **adapted** to the most diverse ends.

According to Lohr the "malacostracan body, be it an **amphipod** ( ), an **isopod** ( ), a **decapod** ( ), or what not—is composed of a series of twenty[1] segments, each of which is essentially of the skeletal plan shown in the diagram, except that the appendages of the foremost segment are typically unbranched and the hindmost segment (the telson) is rudimentary and bears no appendages at all. Some of these segments may become fused together and consolidated on the dorsal side, only the appendages and ventral margins remaining free. This may occur at either end of the body, but **it occurs constantly in the five front segments,** these by fusion forming the head. The appendages of these five segments **always consist of two pairs of antennae at the front, one pair of mandibles beside the mouth, and two pairs of maxillae following the mandibles."** These parts and their functions will readily be understood a little later because of their likeness to the parts bearing the same names in the insects shortly to be studied. "Immediately following the maxillae are one or more pairs of maxillipeds, likewise directed forward beneath the mouth to assist in the manipulation of the food. Then follow legs and swimmerettes in more or less variety, the terminal joints of some of the legs being modified in many cases into highly specialized grasping organs called pincers, or chelipeds, and the swimmerettes being frequently modified to serve reproductive or

[1]This is not counting a vestigial segment in the head region, that is discoverable only during embryonic life.



A to D. Diagram of model gastric mill which can easily be made. After W. E. Roth; A, Cardboard as first cut out; B, Model complete at rest; C, Model complete; muscles contracted; D, Median vertical section of model to show folds.

Instructions:

Cut out a piece of card shaped as in Fig. A. Along *ab, cd, ef, hi,* and *mn* cut just the surface of the card with a penknife; do the same, but on the opposite face of the card, along *gk* and *lo.* Then bend slightly downwards the triangular pieces 2, 2; turn 9, 9 under the piece 6, 5, 6 until the lower surfaces of 9, 9 are flat against that of 6, 5, 6; stitch the shaded part of 9, 9 firmly by thread or fine wire to 6, 5, 6; then bend the unshaded part of 9, 9 till at right angles to the shaded part, using *lo* as hinge-line. These projecting pieces of 9, 9 then represent the lateral teeth.

Next bend the piece 1, 3, 4 upon the hinge-line *gk,* until the shaded portion is flat upon the surface of 4, where it must be securely stitched; this done bend back 1, 3 on hinge-line *cf* until 3 is at right angles to 4. The projecting end of 4 made prominent by these folds represents the central tooth. The piece 1 must now be bent gently downwards upon 3, using *cd* as hinge-line, and 4 must be bent sharply on 5, using *mn* as hinge-line. Lastly, perforate the corner of 6, 6 and of 2, 2, and by a single wire (to allow a certain amount of rotation) unite right hand 2 to right hand 6, and left hand 2 to left hand 6, in each case 2 being outside 6. To do this 6, 5, 6 must be bent like a bow, its right and left arms being thrust downwards and inwards. The model will then be as in Fig. B.

If now the pieces 8, 8 and 7, 7, which represent the anterior and posterior gastric muscles, are pulled so as to represent the effect of a muscular contraction the three teeth come sharply together, but are separated again and the whole model brought back to its original condition by the elasticity of the cardboard. Of course in the actual stomach of the crayfish the gaps between the ossicles are filled in with thin, flexible chitin. By carefully adjusting the size and direction of the 3 teeth in the model and further by hardening them with sealing-wax or similar material, they may be made to grind bread, etc., into small fragments. A sectional view is shown in Fig. D.

E. Stomach or "gastric mill" of the crayfish cut through the middle. *c,* cardiac regions of stomach; *d.l.,* duct from the liver; *g,* gastrolith, or calcareous disk secreted by the walls of the stomach; *i,* intestine; *l.t.,* lateral teeth of grinding apparatus; *m.t.,* median tooth; *oe,* œsophagus; *py,* pyloric region; *v,* valve between cardiac and pyloric regions of stomach. (After Hatschek and Cori.)

respiratory functions. The eight segments following the head constitute the thorax and the seven last segments (counting the rudimentary twentieth segment), the abdomen.

"Crustaceans being primitively free-swimming aquatic animals, it is their swimming appendages that are **least altered by adaptations.** The legs are the stoutest of the appendages, and these offer but one branch arising from the basal piece, and that composed of a reduced number of highly differentiated segments. A comparison of a leg with the last maxilliped in the crayfish will show which appendage has been lost and which preserved and specialized. The best clues to interpretation of homologies in any appendage are likely to be found in other adjacent appendages, which, because of proximity, have been subject to somewhat similar influences."

THE DIGESTIVE SYSTEM

Crayfish live chiefly on living snails, tadpoles, young insects, and the like, but sometimes eat one another, and may also devour decaying organic matter. They feed at night, being most active at dusk and daybreak. The **maxillipeds** and **maxillae** hold the food while it is being crushed into small pieces by the **mandibles.** The food particles pass down the **oesophagus** into the anterior, **cardiac chamber of the stomach,** where they are ground up by a number of **chitinous ossicles** forming the **gastric mill** (Fig. 205). When fine enough, the food passes through a sieve-like strainer or **hair-like setae** into the **pyloric chamber** of the stomach; here it is mixed with a **secretion from the digestive glands** brought in by the **hepatic ducts.** The dissolved food is absorbed by the walls of the intestine. Undigested particles pass on into the posterior end of the intestine, where they are gathered together into faeces, and egested through the anus.

THE CIRCULATORY SYSTEM

As in the frog, the nourishing fluid, the blood, is pumped by the heart (Figs. 206, 207) through the arterial system to the different parts of the body. The blood of crayfish is generally colorless or pinkish in hue, but on standing, especially if exposed to air, it assumes a bluish color. This is due to **haemocyanin,** a respiratory protein, which has copper in its nucleus.

Before moulting, the blood of the crayfish is pink in color, due to a dissolved pigment, **tetronerythrin,** a lipochrome, which is probably deposited in the new chitinous covering, since it is present in less quantity in the blood after the complete formation of the new exoskeleton.

The blood of the crayfish transports food, gases, and wastes, **quite** as does the blood of the frog.

The crayfish does not possess a true venous system and the **heart** has only a single large cavity. The open spaces in the animal's body through which the blood is returned to the heart are called **sinuses.**

The heart itself, lying close to the dorsal surface of the midline, constricts when filled with blood. This constriction sends blood **posteriorly** through the **dorsal abdominal artery,** which lies on the dorsal surface of the intestinal tract, and through a short branch known as the **sternal artery,** which **passes downward** crossing the intestinal tract. The blood is also thus sent to the **ventral thoracic artery anteriorly, and posteriorly** to the ventral part of the body through the abdominal artery.

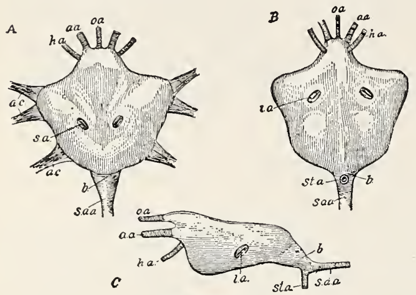


Fig. 206.

Astacus fluviatilis. The heart A, From above; *B,* from below; *C,* from the left side; *a.a.,* Antennary artery; *a.c.,* alæ cordis, or fibrous bands connecting the heart with the walls of the pericardial sinus; *b,* bulbous dilatation at the origin of the sternal artery; *h.a.,* hepatic artery; *l.a.;* lateral valvular apertures; *o.a..* ophthalmic artery; *s.a.a.,* superior abdominal artery; *st.a.,* sternal artery in *B* cut off close to its origin. (From Dougherty after Huxley.)

The arteries passing out of the anterior portion of the heart are the **ophthalmic,** supplying the stomach oesophagus, and head, and the two **antennary,** carrying blood to the stomach, antennae, excretory organs, and the various other tissues of the head. The **two hepatic arteries** lead to the digestive glands.

When the blood is forced through the arterial system, the heart naturally collapses, and the blood which has been sent out forces the blood which is then present in the arteries to be sent forward through the glands. The function of these glands is similar to that of the lungs in the higher forms of animals, aerating the blood and sending it to the large open place around the heart known as the **pericardial sinus.** The heart itself has **two openings on both dorsal and ventral surfaces,** and **one on each side.** The heart muscles, after constriction, again expand and the blood in the pericardial sinus seeps through the six heart openings, filling the cavity. Each of the openings possesses a valve which prevents the blood from passing out, except through the arterial channels.

It is interesting to note that this method is just the reverse of that occurring in fishes where the blood passes through the heart first and thence to the gills, while in the crayfish it is the returned blood that passes through the gills before reaching the heart.

Unless colored matter of some kind is injected into the circulatory system, the student will probably have some difficulty in finding either heart or arteries.

Valves are present in all the arteries at the point of connection with the heart, and blood passes into numerous capillaries and thence into the open spaces between the tissues, until it reaches the external sinuses, from which it enters the gill channels, to pass into the gill filaments where oxygen from the water in the branchial chambers is exchanged for the carbonic acid held in solution in the blood. From here it passes by way of other gill channels into the branchio-cardiac sinuses; thence to the pericardial sinus into the heart.

THE RESPIRATORY SYSTEM

The crayfish, living in, and breathing through water, has **branchial chambers**, which contain gills (Fig. 204, B) instead of lungs, to form its respiratory system. These gills are **pyramidal** in shape and are thrown out into many flaps or **lamellae** closely packed together. Each gill has a **ventral and a dorsal vessel** through which the blood from the **body cavity** passes into the gills, spreading out through tiny **capillaries** into the **lamellae** ( ). These capillaries are continuous with similar capillaries emptying into the dorsal vessel.

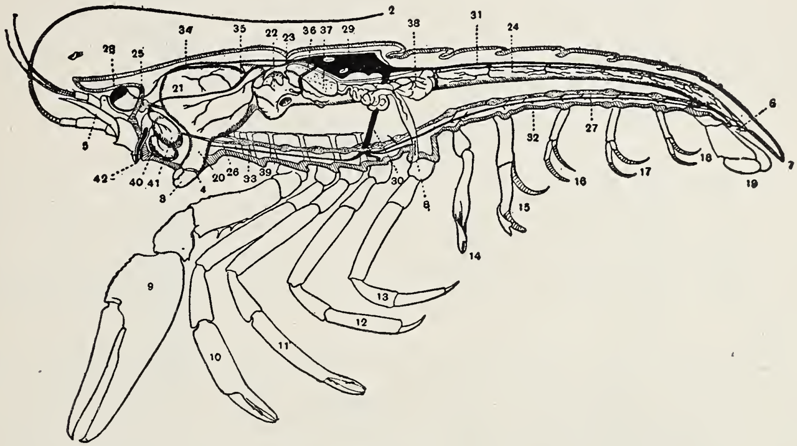


Fig. 207.

Semi-diagrammatic view of internal organs, and some limbs of right side of a male Crayfish. *Astacus fluviatilis*. 1. Antennule. 2. Antenna. 3. Mandible. 4. Mouth. 5. Scale or squama of antenna, exopodite. 6. Anus. 7. Telson. 8. Opening of vas deferens. 9. Chela. 10. 1st walking leg 11. 2nd walking leg. 12. 3rd walking leg. 13. 4th walking leg. 14. 1st abdominal leg, modified. 15. 2nd abdominal leg, slightly modified. 16. 3rd abdominal leg. 17. 4th abdominal leg. 18. 5th abdominal leg. 19. 6th abdominal leg, forming with telson the swimming paddle. 20. Œsophagus. 21. Stomach. 22. Mesenteron, mid-gut. 23. Cervical groove. 24. Intestine. 25. Cerebral ganglion. 26. Para-œsophageal cords. 27. Ventral nerve-cord. 28. Eye. 29. Heart. 30. Sternal artery. 31. Dorsal abdominal artery. 32. Ventral abdominal artery. 33. Ventral thoracic artery. 34. Ophthalmic artery. 35. Antennary artery. 36. Hepatic artery. 37. Testis. 38. Vas deferens. 39. Internal skeleton. 40. Green gland. 41. Bladder. 42. External opening of green gland. (From Latter after Howes.)

The venous blood in all parts of the body other than the gills, passes through what is called an **open sinus system**, whereas in the gills themselves the **anastomosing arch of the arterial and venous capillaries forms a closed system.**

The thin-walled flaps of the gills are in contact with the water, which is sent through the branchial chamber by the muscles of the **scaphognathite** ( ), a sort of scoop consisting of the **fused bract and exopodite** of the second maxillae. This scoop bales the water out of the forward end of the gill chambers. The **swimmerettes,** being in constant motion, send water forward **to** the gill chambers. The blood thus comes in contact with fresh water, is **aerated,** and gives off its **carbon dioxide.** The gills which are **on** the appendages themselves, are called the **podobranches** ( ), while those on the **basal part** of the appendix are called **arthrobranches** ( ), on account of being on the joint itself, and those which originate on the body-wall are the **pleurobranches** ( ).

THE EXCRETORY SYSTEM

Contrasting interestingly with many of the other animals studied in the laboratory, the excretory organs of the crayfish are in the head region. They consist of two rather **large, green glands** (Fig. 207), just in front of the oesophagus, with a thin-walled dilated portion called the **bladder,** and a **duct** opening to the exterior through a **pore** at the top of a **little elevation on the basal segment of the antenna.**

THE NERVOUS SYSTEM

The nervous system (Fig. 208, B) is very much like that of the earthworm. The central nervous system is made up of a **ventral chain of nerve ganglia,** though it lies dorsal to the ventral blood vessel. The ventral chain possesses a **ganglion** for practically every segment, from its posterior end forward. The seventh is called the **sub-oesophageal** ganglion.

The brain sends nerves to the eyes, antennules, and antennae. The sub-oesophageal ganglion, lying in segment seven, is made up of the ganglia from segments three to seven fused together. These send nerves to the mandibles, maxillae, and first and second maxillipeds. **Visceral nerves** are also supplied from the brain, extending posteriorly to the viscera.

THE SPECIAL SENSE ORGANS

Each eye (Fig. 208, A) is made up of some 2,500 little square facets. The long rod extending immediately behind each facet is called an **ommatidium.** It is supposed that the crayfish can thus see moving objects much better than it could if it had an eye similar to higher forms. But there being so many facets, it is assumed that the animal obtains what is called a **mosaic image,** an image made up of a great many separate and distinct views. However, as Latter says, "We must not confuse the image we think the animal obtains with the impression that is given it, for the human eye sees an inverted image but the impression is just the opposite."

Although each ommatidium has a small range of vision and forms a **stiple** or **mosaic** image, it has been calculated that the range of adjoining ommatidia overlaps so that a continuous picture or image is formed.

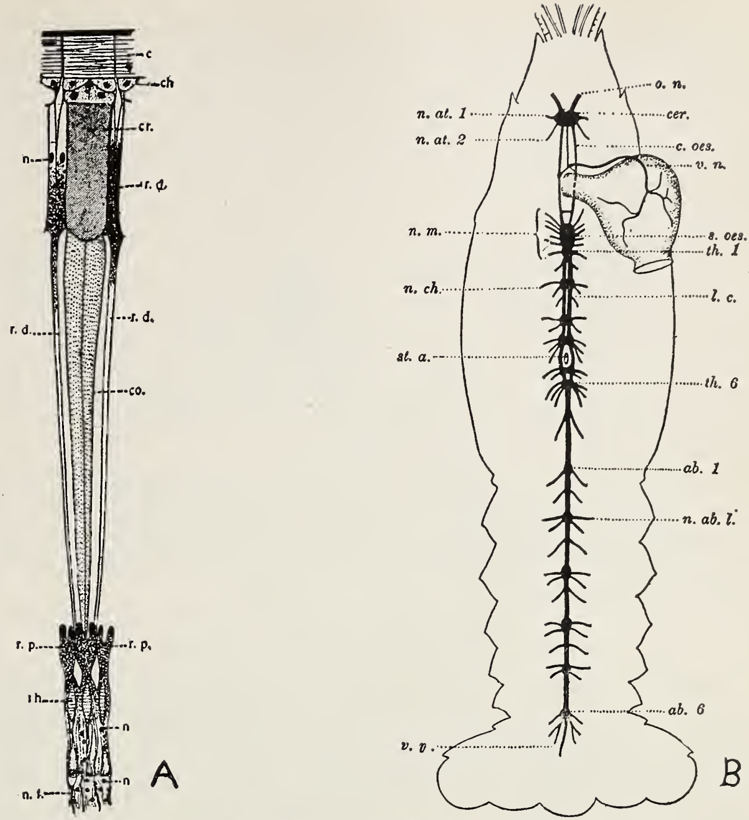


Fig. 208. Ommatidium and Central Nervous System.

A. An ommatidium or eye-element from the eye of the *Lobster*. *c*, cornea (cuticle); *ch.*, corneal hypodermis, which secretes the cuticle; *co.*, cone cells; *cr.*, crystalline cone; *n*, nuclei; *n.f.*, nerve fibres; *r.d.*, distal or outer retinula cells; *r.p.*, proximal or inner retinula cells; *rh.*, *rhabdome.* (After G. H. Parker.)

B. A semi-diagrammatic view of central nervous system of a crayfish. *ab.*1, *ab.*6, The first and sixth abdominal ganglia; *cer.*, cerebral ganglion; *c.œs.*, circumœsophageal commissure; *l.c.*, longitudinal commissures of ventral cord; *n.ab.l.*, nerves to abdominal limbs; *n.at.*1, nerve to antennule; *n.at.*2, nerve to antenna; *n.ch.*, nerve to cheliped; *n.m.*, nerves to limbs adjoining the mouth; *o.n.*, optic nerve; *s.œs.*, subœsophageal ganglion; *st.a.*, sternal artery; *th.*1, *th.*6, first and sixth thoracic ganglia; *v.n.*, nerve to proventriculus; *v.n'.*, nerve to hind-gut. (After Borradaile.)

Thus, three adjoining facets might view the word "Biology" in this way:

Bio olo ogy.

That is, facet one, would see the first three letters, facet two the middle three, and facet three the last three. But since the range of each facet overlaps that of the adjoining, the image formed is actually this:

Bio ogy
olo

In other words, instead of an **apposition image** or mosaic, a **superposition image** or continuous picture is formed.[1]

[1] Microphotographic studies have definitely demonstrated that the account here given is the correct one.

It is doubtful whether the crayfish can hear. Some of the older texts in biology speak of an **otocyst** ( ), but the newer ones have discarded this name entirely; for that organ, which was supposed to be used for hearing, has come to be considered a **balancing organ** by which the animal knows whether or not it is right side up and which, thereby, makes it possible for the crayfish to adjust its position and direction.

These little chitinous lined sacs on the basal segment of each antennule are now called **statocysts** ( ). There are a number of **sensory hairs** in this sac and a few grains of sand called **statoliths.** These latter are placed there by the crayfish itself. These little sand grains coming in contact with the sensory hairs make it possible for the animal to determine its direction and position while swimming. The statocysts are therefore called **organs of equilibrium.** The statocysts are shed whenever the animal molts.

We do not know whether the crayfish has a definite sense of smell or not. When meat juices or tiny particles of meat are so placed in the water that a slight current, carrying some of the meat, comes close to the animal's feelers, it begins working its jaws. This may, however, be either a sense of touch, or taste, or smell.

MUSCULAR SYSTEM

As the crayfish possesses an exoskeleton, all of the muscles are attached to the interior of its casing. The strongest muscles are in the abdomen. It is by means of these that the abdomen can be bent quickly and easily, producing a powerful stroke in the water and shooting the body backward rapidly. All of the appendages are also supplied with muscles. The muscles are very beautifully arranged, though quite complicated and rather difficult to work out.

REPRODUCTION

Crayfish are **dioecious,** that is, the two sexes are separate (Fig. 209). The male (Cambarus) possesses tri-lobed testis (one pair lies anteriorly and a single lobe lies posteriorly) in which the spermatozoa arise. The spermatozoa pass through the **vasa deferentia** ( ) out of the paired **genital openings** in the last pair of thoracic legs.

In the female there is a bi-lobed ovary in which the eggs are found. These, upon ripening, pass through the parent oviducts out of the genital openings, one of which is located in each base of the third walking leg. The sperm are transferred from the male to the **seminal receptacle** of the female during copulation, which takes place most frequently in the autumn. The seminal receptacle itself is a cavity in the fold of the cuticle between the fourth and the fifth pairs of walking legs.

The eggs are usually laid in April and probably fertilized at that time. The female exudes a sticky substance upon the swimmerettes after lying upon her side for several days and cleaning and polishing them very thoroughly. When the eggs are laid, they adhere to the swimmerettes which are moved back and forward through the water, thus aerating the eggs. It takes from five to eight weeks for the eggs to

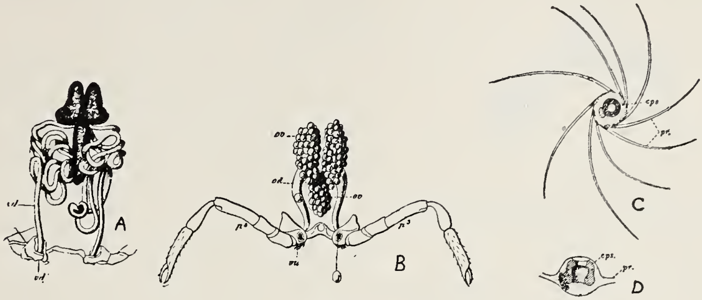


Fig. 209.

A. Male reproductive organs of crayfish. *t.*, Testes; *vd.*, vas deferens on last walking leg. (After Huxley.)
B. Female reproductive organs of crayfish. *ov.*, Ovaries; *ov'.*, fused posterior part; *od.*, oviduct; *vu.*, female aperture on the second walking leg. (After Suckow.)
C. Spermatozoa of a crayfish. *C.* Whole spermatozoon from above; *D*, part, enlarged, from the side. *cps.*, Capsule; *pr.*, stiff processes. (After Borradaile.)

hatch, the larvae clinging to the egg shell. In about two days the first **molting** or **ecdysis** takes place. Like any animal possessing an exoskeleton the crayfish finds it impossible to grow without splitting its exterior covering and getting a new one to take its place.

The young stay with the mother about a month, then shift for themselves. Crayfish attain an age of approximately three or four years. They molt at least seven times during the first summer.

REGENERATION

We have seen how the earthworm, if it is divided in a region posterior to the vital organs, will grow a new tail for the forepart, as well as a new tail-like portion on the tail itself. In the latter case, the animal starves to death, because there is no way of eating.

With the flatworm **Planaria,** all manner of fantastic forms may be grown by cutting off, or splitting, or grafting. The crayfish, too, possesses the power of regeneration to some extent, though nowhere nearly as much as the worms. If a leg, eye, or pincer is destroyed (Fig. 210), the animal grows a new appendage, though in place of an eye, it may, and often does, grow an appendage quite similar to one of the walking feet, or even a pincer, depending on how much of the original appendage was destroyed.

AUTOTOMY

An interesting condition of the crayfish, as well as of some of the other crustaceans, is the breaking off, by the animal itself, of one or more of its legs when caught in a position where it seems incapable of extricating itself.

At certain points in the legs, there is a thick diaphragm with a tiny hole through which blood passes, and it is here that the animal breaks off its own leg, the tiny drop of blood there exposed **coagulating** almost immediately and thus preventing its bleeding to death.

Fig. 210.

Diagram showing antenna-like organ regenerated in place of an eye of *Palæmon.* (From Morgan, after Herbst.)

With an open blood system, such as the crayfish has, bleeding to death would be an easy matter were this special arrangement not made in the animal. A new leg, as large as the one lost, will develop from the stump thus remaining.

Reed declares that "autotomy is not due to a weakness at the breaking point, but to a reflex action, and that it may be brought about by a stimulation of the thoracic ganglion as well as by a stimulation of the nerve of the leg itself."

It will be seen quite readily that this power of autotomy is of considerable advantage to an animal.

PARASITIC CRUSTACEA

Sacculina ( ). (Fig. 212.)

The young **are** active free-swimming larvae much like a young **prawn** ( ) or young crab. The adult bears absolutely no resemblance to a typical crustacean such as a crayfish or crab. **Sacculina**, after a short period of independent existence, penetrates the abdomen of a crab, and completes its development while living as a parasite in the crab. In its adult condition, it is simply a great tumor-like sac, bearing many delicate root-like suckers which penetrate the body of the crab host and absorb nutriment. **Sacculina** has no eyes, no mouth parts, no legs, or other appendages, and hardly any of the usual organs except reproductive organs. **Degeneration** here is carried very far.

There are various other parasitic crustacea, such as the numerous kinds of fish lice which live attached to the gills or other parts of fish, and derive their nutriment from the body of the fish. These also show various degrees of degeneration. With some of the fish lice the female, which looks like a puffed-out worm, is attached to the fish or other aquatic animal, while the male, which is perhaps only a tenth the size of the female, is permanently attached to the female, living parasitically on her.

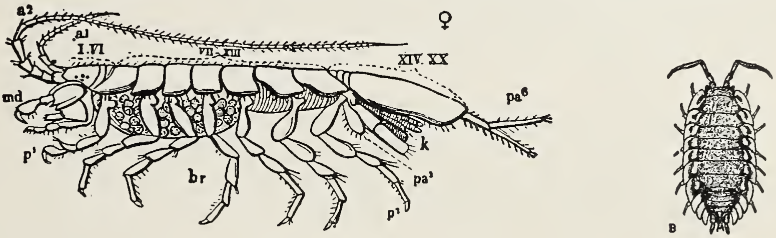
PLANKTON

One may, with a fine-meshed net, sweep in a considerable collection of organisms from the surface of ponds, lakes, rivers, or ocean. There will be thousands of minute creatures of varying shape and size. Some of them are too small to be seen with the naked eye, while others are easily noticed. Collections of this kind may be made from any waters at any time of the year, from thousands of miles out at sea, and over depths of thousands of feet, to the shore line itself. The reason organisms can be found everywhere in water is due to the fact that their whole life is spent **afloat**, beginning with the egg and reaching through the adult stage. Living organisms of this type have been called **plankton**, and comprise protozoa, algae, diatoms, rotifera, and small crustacea, the latter being especially noticeable.

To permit a life afloat, organisms are provided with various types of **adaptations**, such as minute droplets of oil, long spines to add buoyancy, and gelatinous envelopes. Among the small crustacea, spines and oil drops are especially abundant. Upon analysis it has been shown that the oil of fish is derived from these small crustacea. The reason for this is easily understood when it is known that the sole food of several species of whale and of many fish is plankton.

TERRESTRIAL CRUSTACEANS

The class **Malacostraca** ( ) are arthropoda, usually of large size, with five segments in the head, eight in the thorax, and six in the abdomen, and a gastric mill in the stomach. These, like all other classes, are divided into orders. Prominent among these orders



A

Fig. 211.

A. Ascellus aquaticus a^1 a^2 antennae; *br*, brood-pouch; *k*, pleopoda modified to gills; *md*, mandibles; p^1-p^7, thoracic feet; pa^1-pa^6, abdominal feet (pleopoda); I-VI, head; VII-XIII, thoracic segments; XIV-XX, abdominal segments partly fused. (After Hertwig.)
B. Oniscus asellus, a terrestrial species. (After Paulmier.)

are the **Decapoda** ( ). The crayfish comes under this grouping. All members of this order have the first three pairs of thoracic limbs specialized as maxillipeds, and possess five pairs of thoracic walking-legs, while all the thoracic segments are generally covered by the carapace. They also have stalked, compound eyes.

The **Isopoda** ( ) have a body that is long and flat (Fig. 211, A), seven free thoracic segments, leaf-like legs, and no carapace. There are no gills in the thorax.

The five anterior pairs of pleopods are modified for breathing purposes, the endopodites are thin-walled plates, and the exopodites and the whole first pair of pleopods serve as a gill-cover.

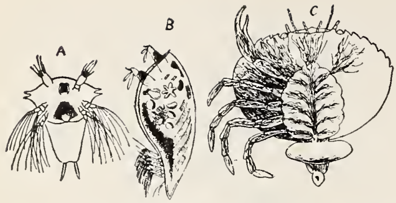


Fig. 212.
Development of the parasitic crustacean, *Sacculina carcinus:* *A,* Nauplius stage; *B,* cypris stage; *C,* adult attached to its host, the crab, *Carcinus maenas.* (After Hertwig.)

In the terrestrial **Isopoda** (Fig. 211, B)—the wood-lice—the gills are adapted for breathing damp air. In these, the first and second-gill-covers have air-tubes within them. These function like the tracheae of insects and are, therefore, **physiologically, but not morphologically, comparable** to tracheae.

The many different species of **Isopoda** (except the wood-lice) are aquatic. There are many which are parasitic, feeding on both dead and living fish, and fish in turn feed on them.

A very remarkable finding in the parasite **Cymothoidae** ( ), by Buller, is that the same individual can be developed first as a male and then as a female.

Cryptoniscus ( ) is a more or less shapeless sac which attaches itself to the stalk of **Sacculina** (Fig. 212), and after the host (which is itself a parasite) is killed, the new parasite uses the "roots" of **Sacculina** to draw forth its own nourishment.

The **Entoniscidae** ( ), which are parasitic, are usually hermaphrodite, although there are small males, called "complemental males," attached to the larger female.

CHAPTER XXII

INSECTS AT LARGE

IT is well first to note that insects (often wrongly called **Hexapoda,** on account of their having three pairs of legs), are winged, six-legged arthropods **(Pterygogenea)** ( ) (Fig. 213). The body is divided into three distinct regions—the **head,** the **thorax,** and the **abdomen.** The head has the following appendages: a single pair of **antennae** ( ); usually **two compound eyes; three simple eyes called ocelli** ( ); and **four different kinds of mouth-parts.** These mouth-parts consist of a **labrum** (single, and not one of the series of metameric appendages), **mandibles, maxillae,** and **labium;** these last three being paired.

The thorax is composed of three segments—**prothorax, mesothorax,** and **metathorax.** Each segment is protected by four exoskeleton plates —a dorsal **tergum,** a ventral **sternum,** and two lateral **pleura.** There is a pair of **walking legs** on each thoracic metamere, while the last two usually also have a **pair of wings** attached.

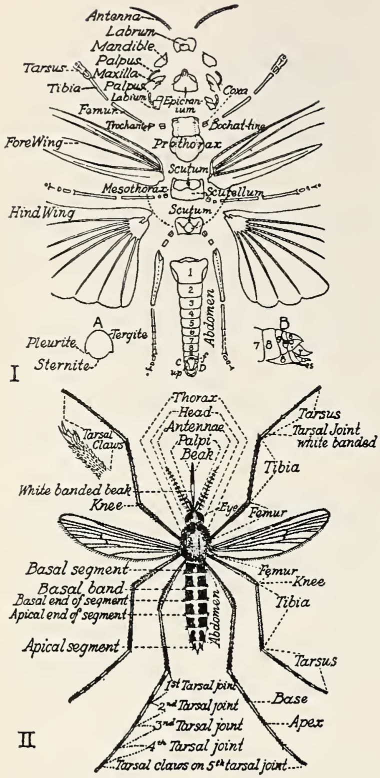
The abdomen usually consists of eleven segments, on which there are no appendages except **accessory reproductive organs** and sometimes a **sting** at the posterior end.

In general there are two types of mouth-parts. These may vary considerably. Grasshoppers and beetles have **biting mouths,** while the **true bugs** have mouths arranged for sucking, and some insects, such as the bee, have specialized mouth-parts which may be used for either biting or sucking.

The walking legs have five parts: a proximal **coxa** ( ), often fixed immovably to the sternum to which it is attached; a short **trochanter** ( ); a long **femur;** a slender **tibia;** and a **jointed tarsus,** usually provided with little hooks or pads at its free ends. As insects have varying modes of life, such as swimming, flying, digging, and leaping, the legs of each type of insect are **adapted** to the particular functions required.

It is from the last two thoracic segments that the wings arise. The wings are of two types: Broad ones, such as the butterfly possesses, used for sailing; and smaller ones like those on flies, which can be moved quickly to cause a rapid movement of the animal. There may be scales or hairs on the wings. Likewise, wings may be thick or thin, light or heavy, and vary in many other ways. The so-called "veins" in insect wings are not veins at all, but thickenings supporting the wings.

As insects are complex organisms, all the interior structures nor-

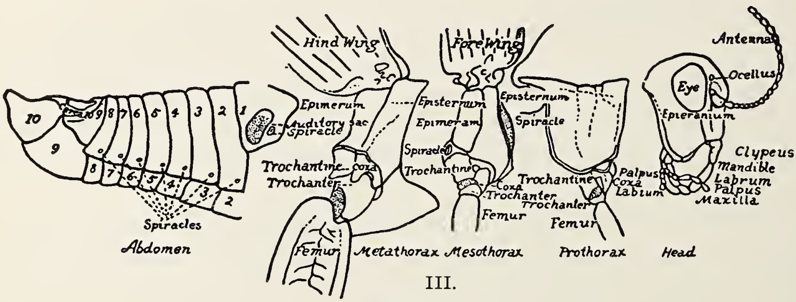


mally found in any animal, are also found in them, though these may vary considerably as to shape and size. For example, those insects, which feed on vegetation, have longer digestive tracts than do those feeding on animal matter.

The parts of the digestive system (Fig. 214, E) are: The **mouth** or **buccal cavity**; a slender **oesophagus,** dilated to form a thin-walled **crop**; a muscular **gizzard** or **proventriculus**; a **glandular stomach,** or **ventriculus,** from which little pouches, or **caeca,** branch out; and a long slender **intestine.** At the junction of the stomach and intestine, the slender **Malpighian tubules** discharge their excretions into the alimentary canal.

As distinguished from the higher forms of life no air-breathing insects have lungs. They receive their oxygen through a network of tubes, called **tracheae,** which open through little **spiracles** (   ) along the sides of abdomen and thorax (Fig. 215).

If, therefore, one wished to chloroform or drown an insect, it could not be done by covering the head or placing the head under water. The abdomen and thorax would have to be covered with the anaesthetic or the water.



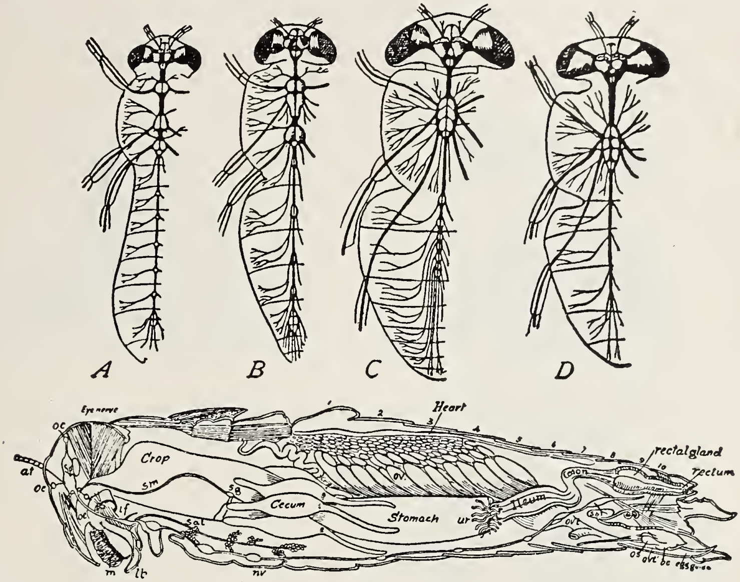
III.

Fig. 213.

I. External anatomy of *Caloptenus and spretus,* the head and thorax disjointed; *up,* Uropatagium; *f,* furcula; *c,* cercus. (Drawn by J. S. Kingsley.)
II. An adult mosquito much enlarged, with all the parts that are used in classification named. (Smith, N. J. Experiment Station, Bulletin 171, 1904.)
III. Side view of Locust with the Thorax separate from the head and abdomen divided into three segments. (I, III, from Packard's "Zoology," by permission of Henry Holt & Co.)

If the insect flies a great deal, these tracheae are expanded into **air sacs,** which adds to the lightness of its body.

However, insects which live in water, have tracheal or blood gills, or both, or at least some specialized adaptation by which oxygen may be used.



E.

Fig. 214.

A.-D. Successive stages in the concentration of the central nervous system of Diptera. *A, Chironomus; B, Empis; C, Tabanus; D, Sarcophaga.* (After Brandt.) *E.* Internal anatomy of *Calopte'nus femur-rubrum*: *at,* Antenna and nerve leading to it from the "brain" or supra-esophageal ganglion *(sp); oc,* ocelli, anterior and vertical ones, with ocellar nerves leading to them from the "brain;" *oe,* œsophagus; *m,* mouth; *lb,* labium or under lip; *if,* infra-esophageal ganglion, sending three pairs of nerves to the mandibles, maxillae, and labium respectively (not clearly shown in the engraving); *sm,* sympathetic or vagus nerve, starting from a ganglion resting above the œsophagus, and connecting with another ganglion *(sg)* near the hinder end of the crop; *sal,* salivary glands (the termination of the salivary duct not clearly shown by the engraver); *nv,* nervous cord and ganglia; *ov,* ovary; *ur,* urinary tubes (cut off, leaving the stumps); *ovt,* oviduct; *sb,* sebaceous gland; *bc,* bursa copulatrix; *ovt',* site of opening of the oviduct (the left oviduct cut away); 1-10, abdominal segments. All other organs labeled in full. (Drawn from his original dissections by Mr. Edward Burgess.) (From Packard's "Zoölogy," Henry Holt & Co., Publishers.)

A peculiar feature of all animals possessing an exoskeleton is that as soon as the inside of such skeleton grows but slightly, it becomes too large for its skeletal-jacket, so that it must split and a new one must form. This is called **ecdysis** (   ), or molt (Fig. 227), and the periods between molts are called **instars.**

It will be remembered that we spoke of a double-life in the frog, not only as applied to its living in water and on land, but as to its beginning life looking very much different from what it does as an adult. Practically all insects go through a **metamorphosis** (   ) of some sort, and this is much more complicated than the change undergone by the frog.

When insects hatch from eggs (Fig. 241, I, II), and are unlike their parent-forms, they are said to be **heterometabolous** ( ). Such insects hatch as **nymphs** ( ), a wingless form gradually growing larger and larger wings after each ecdysis until the adult form is reached. Insects are **holometabolous** ( ) if there is a complete metamorphosis, such as being born a **worm-like larva** ( ), which takes food for a short time and then

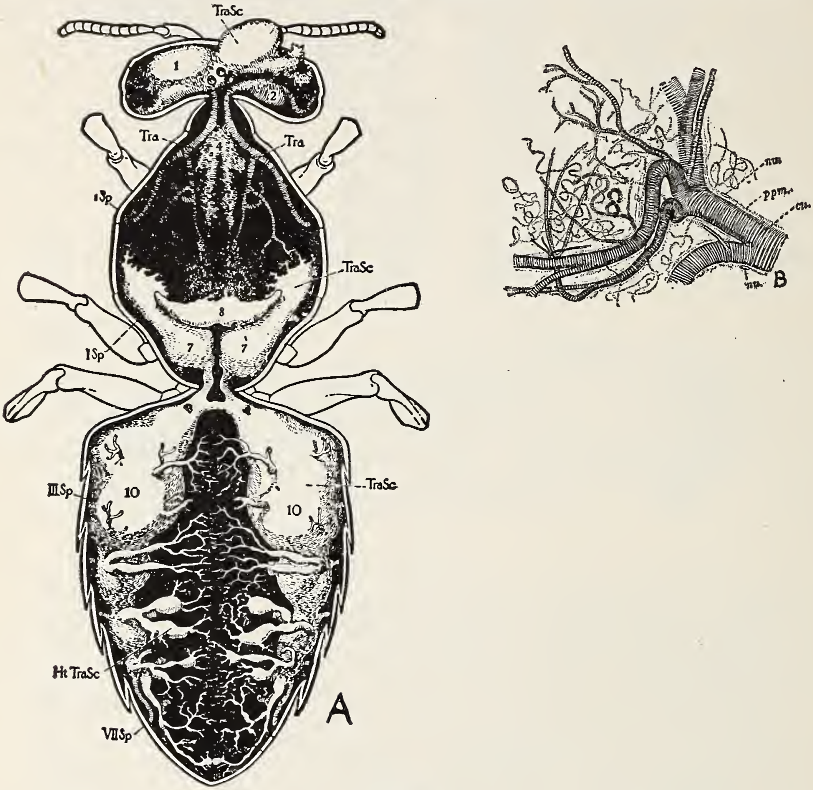


Fig. 215.

A. Respiratory system of worker honey-bee as seen from above, one anterior pair of abdominal sacs removed and transverse ventral commissures of abdomen not shown. *I sp, III sp, VII sp*, spiracles; *HtTraSc, Tra Sc*, 1, 2, 4, 7, 8, 10, tracheal sacs; *Tra*, tracheae. (From Snodgrass, Tech. Series 18, Bur. Ent., U. S. Dep't of Agric.)

B. A portion of the tracheal tissue of a cockroach, highly magnified. Only parts of the tubes are in focus.

cu., Cuticular lining with spiral thickening; *nu.*, nuclei of the protoplasmic layer; *ppm.*, protoplasmic layer continuous with the epidermis ("hypodermis") of the surface of the body. (After Borradaile.)

goes into a **resting** or **pupal** stage during which no food is taken, and during which time it loses all its larval structures, finally developing into a complete adult insect, known then as an **imago** ( ).

In those cases where there is no metamorphosis, the animals are said to be **ametabolous** ( ).

CHAPTER XXIII

THE GRASSHOPPER

WE have seen from our study of the crayfish that it was an arthropod—that is, had hollow jointed feet, and that the phylum arthropoda is often divided for convenience into branchiata—(gill-breathing) and tracheata (breathing by air tubes).

The two tracheata most commonly studied in the laboratory are the bee and the grasshopper in this country, and the cockroach in England. Each of these organisms well represents the group to which it belongs. The bee is the more highly specialized, and many books have been written about this interesting animal; in fact, so much so that the subject-matter covering it is almost inexhaustible. The grasshopper, however, because it is considerably larger than the bee, is preferred by many teachers.

The study of this animal is representative of the greater part of the animal kingdom, for this is an insect, and there are more different kinds of insects than there are of all other animals put together.

IMPORTANCE OF INSECT PESTS

Some of our most important garden pests are insects, and it has been estimated by competent authorities, that **one-tenth of all farm products are destroyed by such pests.** Now, there are very few of us who would not object to being obliged to pay one-tenth of all we earned to anyone for the privilege of working. Still, how low our average intelligence is, may be noted from the fact, that while a loss of one-tenth of all our food is constant, year in and year out, the average farmer would object very strenuously to paying out even one-tenth of the tenth he loses to pay the salary of a group of trained men to prevent this loss from occurring. And this is true, even though he would thus be increasing his income to a considerable extent.

Let us illustrate by actual figures. The average farmer, let us say, has an income from all his crops (and this income, of course, includes his living expenses, as he raises the greater portion of his food) at the lowest estimate, of about $2,000 each year. He should have, if the insect pest were controlled, $2,200. Yet, if he were asked to contribute $20 each year to such control he would rebel. But as each and every one of us must live on what the farmer produces, we must pay $2,200 for $2,000 worth of food. That is, we must pay $100 a year extra for every thousand dollars we spend for food.

Let us consider the item of clothes. These may be of cotton, wool, or silk. Cotton and wool are farm products, and so also is silk. The silk grower also must have this extra $100 to pay his own expenses in purchasing food for himself and family. In the silk industry **Pebrine** —a very serious silk-worm disease—reduces the annual production of silk to the extent of thousands of yards and, thereby, raises silk prices.

To make this clear, suppose a man is employed for a certain number of days each week and a certain number of weeks in the year, and is paid $5 a day for such work. It follows that his employer must receive enough money, when selling the product produced, to pay the worker $5 each day, plus a proportionate amount of the rent, taxes, bookkeeping, salesmen's salaries, and traveling expenses, as well as allowing interest on his investment. That is, what the worker gets $5 for, will cost the ultimate user at least $10, for, it is just as difficult to sell and to deliver goods as it is to make them. But now suppose a storm comes up and destroys the plant, and the workman still works,

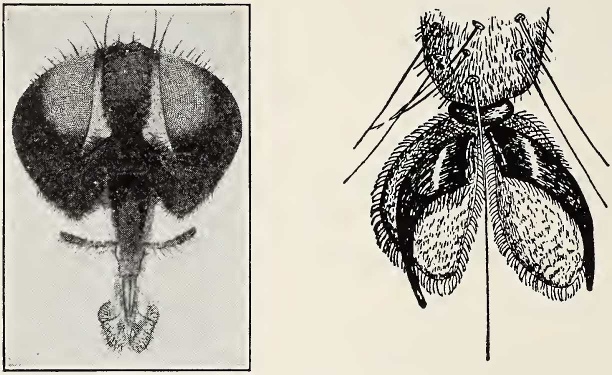


Fig. 216. Head and Foot of Fly.

The Foot shows hooks, hairs and pads. (Head after Herms.)

receiving $5 each day, the traveling salesman still works, the bookkeeper, stenographer, foreman, engineer, fireman, night watchman, are still all kept on the job, and receive their stated pay, but the work is all put into clearing away the debris and in rebuilding. It follows that all of this expense of keeping these men employed must be added to the cost of the article. This loss may be spread over a great many years, it is true, only a cent or two being added to the selling price of the article, but it must nevertheless be paid.

Now, suppose for a moment, that such a fire takes place regularly every year, and that, therefore, one must work one-tenth of the entire year without producing anything. This is equivalent to taking the workman's salary away for this tenth of the year though still obliging him to do the work.

Here is a parallel to the financial loss caused by insect pests alone, to **each of us.** For this is **our loss.** We must work an extra five weeks each year to pay for the fact that men at large rank so low in the intellectual scale that they refuse to pay out $10 a year for each $1,000 they receive to prevent tremendous food and clothing losses.

But this mere working of about five weeks each year for nothing is of little importance compared to the **millions of lives lost** each year by the working out of the self-same principle that makes men think only of the dollar they receive to-day, rather than of the ten-times-that-amount they may have to-morrow, if they will but lay the foundations to-day.

Every worker who dies of a disease which could have been prevented, causes each and every one of us to do a portion of his work. This means that we must actually pay the expenses of keeping up such a one's family without anything being contributed on their part.

There is thus an underlying unity among all human beings, in that, whether we will or not, we are our brother's keeper.

This is again well illustrated by taking into consideration the fact that your own home and property may be as clean as it is possible to keep it, but your neighbor's is not. The flies which breed in his manure pile, or in his garbage heap, will come into your home and deposit the neighbor's filth on your food. That this deposit is no mere trifle is shown by an enlarged sketch of the fly's foot and proboscis (Fig. 216).

EXTERNAL APPEARANCE

The hard exoskeleton has already been mentioned, as well as the segmentation of the grasshopper's body. The segments in this animal are unlike those of the earthworm in not being all alike.

There are a head, a thorax, and an abdomen, to which various jointed appendages are attached, a pair to each segment, where any appendages are found.

The three pairs of legs formerly gave insects the name of **Hexapoda.** Two pairs of wings are usually found upon the dorsal side of the second and third segments of the thorax, while the tiny outer openings of the tracheae—known as **breathing pores,** spiracles, or **stigmata**—are arranged in pairs on each side of two thoracic segments and on all the abdominal segments except the last two or three.

Grasshoppers, as well as crickets and cockroaches, are members of the order **Orthoptera** ( ). All of this group have mouth-parts (Fig. 217), or jaws, formed **for biting and gnawing,** as well as two pairs of straight wings, the first pair thickened, the second pair thin, and, when at rest, folded like a fan under the first pair.

A pair of jointed **antennae,** or feelers, extend forward from the head, while a pair of **large compound eyes,** located on the **dorsal epicranium,** and **three ocelli,** or simple eyes, are readily observed. The mouth-parts consist of the labrum, or upper lips, being hinged to the **clypeus** ( ), a pair of heavy, strong **mandibles,** and a **first pair of maxillae,** with feelers or palps ( ) at the sides; while the **second pair of maxillae** are fused together to form the lower lip, called the **labium**, and are attached to crescent-shaped **genae** (   ). The cheeks are called **genae** (   ), while narrow **postgenae** are back of these.

The maxillae are the **accessory jaws**, and are composed of three regions, the **lacinia** or maxillae proper, the **gulea** (   ),

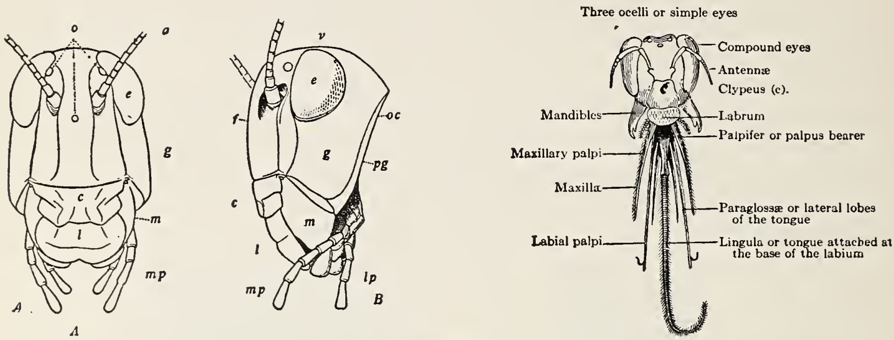


Fig. 217.

A. and *B.* Skull of grasshopper; *C. Melanoplus differentialis.* *a,* Antennae, *c,* clypeus; *e,* compound eye; *f,* front; *g,* gena; *l,* labrum; *lp,* labial palpus; *m,* mandible; *mp,* maxillary palpus; *o,* ocelli; *oc,* occiput; *pg,* post-gena; *v,* vertex. (After Folsom.)
C. Head and Mouth-parts of an insect. (After Tenney.)

the middle spoon-shaped part, and the **maxillary palpus,** a special sense organ. This palpus is in turn composed of various segments, the broad basal piece being called the **stipes** (   ) which joins in turn with a smaller **cardo** (   ).

The lower lip or **labium** is composed of two broad terminal flaps called the **ligula** (   ). The **mentum** (   ) is the basal portion, while the small immovable **submentum** lies between the mentum and the gula.

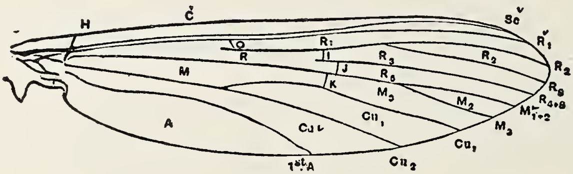


Fig. 218.

The right wing of a male mosquito, *Anopheles maculipennis.* *A,* anal area; *1st A,* anal nervure; *C,* costa; *Cu,* cubitus; *H,* humeral cross-nervure; *I,* cross-nervure between *R* and R_4+_5; *J,* cross-nervure between radial and medial systems; *K,* cross-nervure between medial and cubital systems; *M,* media; *O,* cross-nervure between R_1 and R_2; *R,* radius; *Sc,* sub-costa. (From Sedgwick's Zoology, after Nuttal and Shipley.)

The thorax is divided into a **prothorax, mesothorax** and **metathorax,** easily distinguished by the three pairs of legs, one pair of which is attached to each of the three thoracic divisions. The prothorax constitutes a collar which is drawn out into a **shield** above. The wings, as already stated, are attached to the dorsal side of the mesothorax and metathorax.

The wings are divided by **veins** or **nervures** (Fig. 218) into so-called cells. Although these veins, or nervures, vary considerably in different species, they are quite constant in members of the same species and so are often used as a basis of classification.

The principal longitudinal veins are the **costa** ( ), **subcosta, radius, media, cubitus** ( ), and **anal.**

There are also cross veins. Any variations are the result of either additional and lessened number of those just mentioned. In beetles the fore-wings are sheath-like and called **elytra** ( ). The fore-wings of grasshoppers and all members of the **Orthoptera** grouping are leathery and called **tegmina** ( ).

The abdomen consists of eleven segments, the posterior one less clearly defined than the others.

The entire exoskeleton is divided by **sutures** ( ) into distinct pieces, the **sclerites** ( ), though several of these sclerites may fuse.

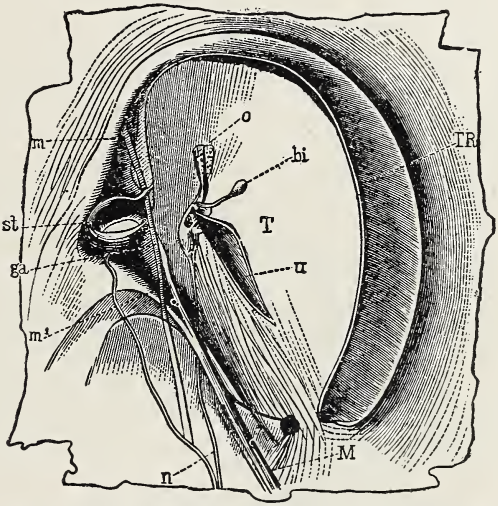


Fig. 219. Ear of Locust *(Caloptenus italicus)* as seen from the inner side.

T, tympanum; *TR*, its border; *o*, *u*, two bone-like processes; *bi*, pear-shaped vesicle; *n*, auditory nerve; *ga*, terminal ganglion; *st*, stigma, or spiracle; *m*, opening muscle, and m^1 closing muscle of same; *M*, tensor muscle of tympanic membrane. (After Graber.)

The sclerites (Fig. 204, A) on the dorsal surface are called **tergites** ( ). These are often fused together in various insects. The sclerites on the ventral surface are known as **sternites** ( ), while the side walls connecting dorsal and ventral sclerites are called **pleurites** ( ).

The **entire dorsal portion** is spoken of as the **tergum** or **notum** ( ); while the **entire ventral** wall is called the **sternum**; and the **lateral wall**, the **pleuron**.

The last tergum is sometimes called the **suranal** ( ) **plate**, while the last sternite forms the **subgenital plate**. Below the level of the eleventh tergite, on each side, there is a triangular **podical plate** ( ), and just above each podical plate and projecting backward from the hind margin of the tenth tergite there is a small **copulatory organ**, the **cercus**. In the female this is extremely small.

The **auditory** ( ) **organs** (Fig. 219) lie on the first abdominal segment. This segment is larger than the others though it does not form a complete ring on account of the hind legs being inserted in it. This auditory organ is merely an oval spot of thin skin stretched across a small cavity and connected with a nerve. This is the ear or auditory apparatus.

The posterior portion of a female's abdomen is more tapering than that of the male and is furnished with four blunt spines (six including the inner guide), to form the egg-laying organ, the **ovipositor**. The tip of the abdomen in the male is turned upward.

The first two pairs of legs on the grasshopper are walking legs while the third pair is used for jumping.

Using one of the first walking legs for detailed study, we find five separate divisions (compare Figs. 203 and 213) into which it can easily be separated, namely, the **coxa** ( ), the shortest joint in close proximity to the body; the **trochanter** ( ), the next succeeding small joint almost entirely fused with the coxa in the grasshopper; the **femur** ( ), a long stout section; the **tibia** ( ) following this, also long and quite narrow; and finally the most **distal** portion, the foot, called the **tarsus** ( ), which is composed of four joints.

There are spines on the leg and claws [also called **ungues** ( )] on the foot; while a **suction disc**, the **pulvillus** ( ), lies between the claws. The longer jumping leg has the same five divisions just mentioned, but the trochanter is fused with the femur, forming a small knob on the inside of the leg.

INTERNAL ANATOMY

THE DIGESTIVE SYSTEM

This consists, as in all the other animals studied, of the **alimentary canal** and the **collateral or accessory organs**, the **salivary glands**, and the **gastric caeca**.

The alimentary canal itself is a long tube extending throughout the entire body. The **mouth** is the first division and is guarded on each side by laterally moving mandibles. Between these mandibles and arising from the inner side of the labium, is the short tongue-like organ known as the **hypopharynx,** at the base of which a tube opens from the several salivary glands. The **epipharynx** is the organ of taste, and is located on the slightly convex surface of the inner side of the labium.

The continuation of the mouth leads into the short curved **oesophagus** which in turn leads to the large **ingluvies** ( ) or crop. Here are seen various rows of spine-like teeth. The **proventriculus,** or **gizzard** ( ), follows. This is a very small organ also furnished with spines; it empties into the large, thin-walled **ventriculus** or **stomach.** Six tubular **gastric caeca,** or **blind sacs,** are attached to the anterior end of the stomach. Posterior to the stomach the alimentary canal forms the intestine which is divided into three portions: the **ileum** ( ), rather slender, with longitudinal ridges on the inside (the infolding ridges increase the absorbing surface); the **colon,** smaller than the ileum and possessing a smooth lining; and the **rectum,** which has six longitudinal rectal glands of unknown function.

The food of the red-legged locust, which feeds quite freely by day (unlike the crickets and katydids which are more active at night), consists of grass and little drops of dew. The pads at the tips of the legs, and the claws, enable the animal to climb stalks of all kinds very readily. This eating of dew rather than drinking at pools of water, has given us the idea that there is something about standing-water that is fatal to the grasshopper. That this idea is correct is evidenced by the fact that grasshoppers kept in captivity must be **sprinkled** with drops of water or they usually perish.

As food is taken into the mouth, the salivary glands pour their secretions forth to assist in preparing it for reception in the crop to which it passes through the **oesophagus.** Here it is mixed with a molasses-colored digestive fluid. It then passes on to be ground up still further by the spinous processes in the muscular gizzard. The various gastric caeca, each of which has an anterior and a posterior pocket, increase the stomach space.

Once the food has passed through the stage just mentioned, it becomes part of the blood of the grasshopper. This it does by being absorbed through the walls of the alimentary tract.

THE CIRCULATORY SYSTEM

The grasshopper has a **long tubular heart** (Fig. 214, E) lying along the dorsal surface just beneath the body wall. From the heart there are **arteries** and **sinuses** connecting the various parts of the body. Due to its position the heart is often called the **dorsal vessel.**

Anteriorly the heart is prolonged into a tube leading to the head and is partially divided by **valves** into eight chambers. The position of the **heart-valves** allows blood to flow **headward only.**

The propulsion of the muscular heart sends the blood forward through various sinuses so that every part of the body is nourished by it. It then returns by a closed tube, the **ventral sinus**, to the **pericardial sinus** or chamber, and enters the heart through several pairs of **lateral ostia** ( ). If more food has been absorbed than can be used, it is stored up as fat in the fat bodies on either side of the heart.

THE RESPIRATORY SYSTEM

The blood of all insects (Fig. 220) contains a respiratory protein, hemocyanin, similar to that of the crayfish. In some few species (bloodworms=midge larvae, **Chironomidae**) hemoglobin is also found. Since the hemocyanin is capable of absorbing oxygen and carbon dioxide, it is probable that in the insects this respiratory protein aids the tracheae in distributing oxygen and collecting CO_2. The tracheae are kept open and extended by a spiral thickening of chitinous lining and extend to all parts of the body even including the legs and wings (Fig. 215, B).

This is, no doubt, one of the reasons why the circulatory system is so poorly developed, for, unlike the higher forms of animal life where the circulatory and respiratory systems are dependent upon each other, the systems in the insects are separate and distinct, so that every part of the body can be supplied with oxygen at any time, regardless of what may happen to another part. The disadvantage of such a method consists in the necessity of having both a respiratory system and a circulatory system in every part of the body instead of having all respiratory work done in one place. The air sacs with which the tracheae are connected are of value in making the animal light for flying and jumping purposes. The grasshopper can beat any professional human jumper by the distance it covers in a single leap when comparative size is considered.

Fig. 220. Blood Corpuscles of the Grasshopper, *Stenobothrus*.

a-f, corpuscles covered with fat-globules, *g.*, corpuscle after treatment with glycerine, showing nucleus. (After Graber.)

If one notices a grasshopper when it breathes rapidly, it will be seen that the abdomen lengthens and shortens, thus forcing air in and out of the spiracles on the thorax and abdomen.

THE EXCRETORY SYSTEM

Like all animals, the grasshopper needs oxygen to carry on its metabolic processes, and, like all animals, it gives off carbon-dioxide as a waste product as well as water and a nitrogen-containing-substance called **urea** (if in solution) or **uric acid** (if crystalline). It is interesting to note that those grasshoppers, which live in dry places, excrete the crystalline product while those, which live in damp places, excrete the soluble form.[1]

The excretory products leave the body through the **urinary** or **Malpighian tubules** which empty into the intestine just posterior to the stomach, thus causing both the excreted and egested material to leave the body in the same way. These tubules ramify throughout the body in the animal and are very conspicuous when the body is opened.

THE NERVOUS SYSTEM

The nervous system resembles that studied in the crayfish. A series of **ganglia** lie along the **ventral nerve cord** which splits at the

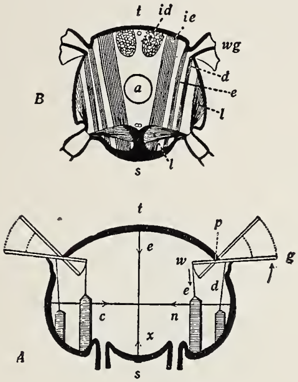


Fig. 221.

A, diagram to illustrate the action of wing-muscles of an insect.
B, diagram of wing-muscles. *a*, alimentary canal; *cn*, muscle for contracting thorax, to depress wings; *d*, depressor of wing; *e*, elevator of wing; *ex.*, expandor of thorax to elevate wing; *id*, indirect depressor; *ie*, indirect elevator; *l*, leg muscle; *p*, pivot or fulcrum; *s*, sternum; *t*, tergum; *wg*, wing. (After Grabers.)

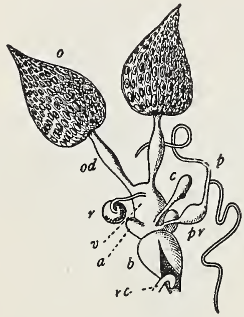


Fig. 222.

Reproductive system of the Queen honey bee. *a*, accessory sac of vagina; *b*, bulb of stinging apparatus; *c*, colleterial, or cement gland; *o*, ovary; *od*, oviduct; *p*, poison glands; *pr*, poison reservoir; *r*, receptaculum seminis; *rc*, rectum; *v*, vagina. (After Leuckart.)

oesophagus, one half passing dorsad on each side of that organ to unite again on the dorsal surface to form the **supraoesophageal ganglion** or **brain.** The ganglion below the oesophagus which branches to permit the passing around to form the brain is called the **suboesophageal ganglion.** It is from the brain that nerves go forward to supply the **special sense organs,** such as the eyes, antennae, and labrum, while the mandibles and maxillae are supplied from the suboesophageal ganglion.

Nerves are given off from the thoracic and abdominal ganglia to all parts of the respective segments. The interesting thing about insects is that these nerve centers seem to be as independent as are the separate

[1]Doubt has been thrown on former investigations by recent work, so it is well not to assume that our opinions in regard to the work of the Malpighian tubules or of the formation of urea are final.

respiratory tracheae in that the head may be removed while the other parts of the body continue their work almost as well as before.

In addition to the **Central Nervous System** and the regular **Peripheral Nervous System** consisting of the segmental nerve filaments, there is also a **Sympathetic System**, divided into two parts, one lying dorsal to the alimentary tract and controlling the digestive processes while the other lies ventral to the alimentary tract and controls the spiracle muscles.

THE SENSES OF INSECTS

We have already seen that there are simple and compound eyes in an insect. An **ocellus**, or simple eye (Fig. 223), is made up of a lens, vitreous body, retina, and nerve, quite like that of the frog, except that the insect's eye is definitely fixed. It cannot accommodate itself to distance. Its power of vision is, therefore, more limited, and because the lens is quite convex and only able to focus at one distance, it is assumed that insects must be very near-sighted.

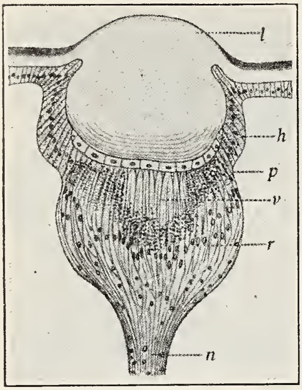


Fig. 223.

Median ocellus of honey bee. (Longitudinal section). h, hypodermis; *l*, lens; *n*, nerve; *p*, iris pigment; *r*, retinal cells; *v*, vitreous body. (After Redikorzew.)

The surface of the compound eye is made up of numerous facets each at the end of a single eye-element called an **ommatidium** (Fig. 208, A), which, as already described for the crayfish, is, in a way, a separate and distinct eye.

Recent investigations of the structure of ommatidia show that these are more or less conical, the narrow end at the base being connected with the nerve fiber. It is assumed that the field of vision of each ommatidium overlaps slightly that of the adjoining ones. This assumption is supported by the fact that the lens of each ommatidium is convex, so that not only rays in direct line but lateral rays are refracted on the nerve fiber. In this way a **superposition image** is formed, not the apposition image, or mosaic, described by older authors.

Recent work on the ocelli and compound eyes indicates both of these structures work together to increase recognition of movement. This is due to the fact that the rays of light reach the ocelli and compound eyes at different angles. There is additional evidence that the ocelli are used to distinguish light from darkness. Certain night-flying bees and dragonflies have greatly enlarged ocelli. Because of the fixed focus of the ocelli and the great convexity of the lens, the object to be seen must be very near.

Whether insects perceive color as such is a question of much dispute. Very little direct evidence is available; most of it is circumstantial. Many authors and experimenters hold that insects recognize colors only as shades of gray, much as a color-blind person does. On the other hand, not a single experiment to prove color vision has demonstrated such a fact. It is not a necessary correlation that because flowers are colored, insects see colors. **Half of the good pollinators are night fliers.**

TOUCH

The sense of touch is probably very highly developed in most insects as there are sensory tactile hairs over the entire body, as well as antennae, palpi, and cerci which are also special tactile organs.

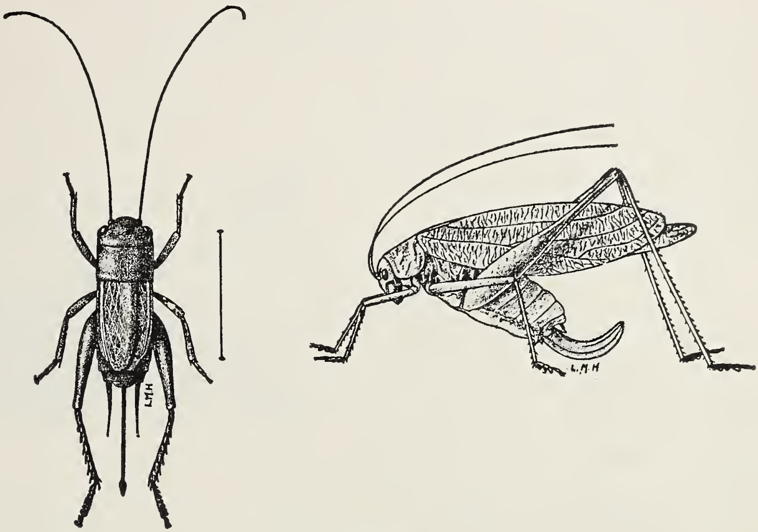


Fig. 224.

A. The common cricket, *Gryllus Pennsylvanicus,* female. Line indicates natural size.
B. Oblong leaf-winged Katydid, *Amblycorypha oblongifolia,* female. (From Kellogg's "American Insects," by permission of Henry Holt & Co.)

TASTE

The sense of taste is located in the sensory hairs; in the microscopic elevations borne upon the tongue or hypopharynx, on the epipharynx (which lies on the roof of the pharynx, and is something like the palate in higher animals), and on the maxillary and labial palpi. From the experiments so far performed it seems insects can detect tastes that man cannot.

SMELL

Insects may depend upon the sense of smell to find their food more than upon sight, but the usual experiments to demonstrate this are far from satisfactory. The cutting away of antennae with the attendant tearing of many tiny nerves will certainly not cause any organism to react normally.

McIndoo has recently shown that the chief olfactory organs (at least in the honey bee) are located near, or on the base of the leg.

HEARING

As various insects produce noises of many kinds, we infer they must hear, though definite evidence has not been forthcoming up to this time. Flies and bees "buzz" by a rapid motion of the wings, while the singing of the male cicada is produced by a rapid vibration of a pair of membranes on the first abdominal segment, and a resounding drum-like membrane within the thorax. Many beetles form a squeaking noise by rubbing their wing-covers against some rasp-like portion of their body while grasshoppers rub their hind legs against the wing-covers and also rub front and hind wings together.

Crickets and katydids (Fig. 224) have a definite scraper on the base of one wing-cover and a file-like apparatus on the base of the other. These are rubbed together causing the neighboring membrane to vibrate and produce the "chirp."

As such "chirps" or calls are answered by their mates it must be assumed that some hearing takes place.

The grasshoppers have a large auditory organ on each side of the first abdominal segment consisting of a surface membrane, or **tympanum,** stretched across a cavity, on the inside of which two tiny processes something like the ear-bones of the frog are found. There are also similar membranes on the tibia of some insects which probably serve as auditory organs.

A male mosquito will vibrate its antennae when a tone is produced on a tuning fork of the same pitch as that made by the wings of the female, so that it may be that in the mosquito the antennae have some auditory function.

THE MUSCULAR SYSTEM

As in all animals possessing an exoskeleton, the muscles must be attached on the inner surface of the skeleton (Fig. 221). Each of these muscles is **innervated** by nerves, however, just as in animals possessing endoskeletons and each muscle moves by a series of complicated pulley-like arrangements already described in the crayfish.

THE REPRODUCTIVE SYSTEM

Among all insects there are two sexes, the male usually being the smaller, more active and more brightly colored. It has been suggested that the reason for this is that the handsomer males are thus able to attract mates more often than those less handsome. Consequently the young born of such more handsome fathers, were also handsome, thus eliminating, by natural selection, the less handsome. It has been suggested by some also that the female, who carries the eggs, by being less gaudy in appearance is also less conspicuous and, therefore, not so likely to be caught by natural enemies.

In all female insects there are a pair of ovaries (Fig. 222) usually formed of many small tubes called **ovarioles.** From the ovaries the **oviducts** pass out into a **terminal region,** the **vagina,** which is sometimes also paired. This latter organ is usually formed by an invagination from the outer part of the body to meet the oviducts. Near the place of meeting of vagina and oviducts or branching off from that region there is a **receptaculum** for receiving and holding the male sperm received during copulation.

Then there are **accessory glands** which secrete a sticky substance, or cement, as the eggs pass through the oviduct. These glands are known as **colleterial** or **sebific** ( ) glands which open in turn into the dorsal portion of a capacious pouch, the **bursa copulatrix,** through a duct. This bursa rests on, and opens directly into, the oviduct of the female. Grasshoppers have an external hard posterior region of the body known as an **ovipositor** (Fig. 225).

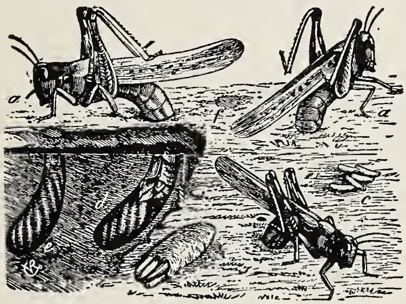


Fig. 225.

Rocky Mountain locust: *a, a, a,* Female in different positions, ovipositing; *b,* egg-pod extracted from ground, with the end broken open; *c,* a few eggs lying loose on the ground; *d, e,* show the earth partially removed to illustrate an egg-mass already in place and one being placed; *f,* shows where such a mass has been covered up. (After Riley.)

The males possess a pair of **testes** usually formed of many small tubes. These tubes, in turn, connect with two ducts, the **vasa deferentia,** which carry the sperm to the terminal portion called an **ejaculatory duct.** The ejaculatory duct may have one or two openings which may be formed by the union of both vasa deferentia or by an invagination meeting these ducts.

The **seminal vesicles,** usually paired, open from either the vasa deferentia or the ejaculatory duct. Here sperm are stored. Often there are accessory glands whose secretion unites the sperm into packets known as **spermatophores.** There may or may not be an external copulatory organ though in the grasshopper there are a pair of these, called **cerci.** Often there are also external hard parts as in the female though, of course, these are not ovipositors.

The sperm are placed in the seminal receptaculum of the female by the male and may remain there for many years. The queen bee only copulates once, and that on her first and only flight, and yet the sperm have remained alive so that eggs which were laid thirteen years afterward were fertile.

There are a few insects which give birth to living young. Such are the parthenogenetic summer aphids, a few flies, the little bee parasites, **Strepsiptera,** a few beetles and cockroaches. But by far the greater portion lay eggs, the young then developing from these.

When eggs develop which have not been fertilized, birth is said to be by **parthenogenesis** ( ). This occurs normally, at least for a number of generations, in two lepidoptera and one beetle, in some coccus insects and aphids, and in certain saw-flies and gall-wasps. It occurs casually in the silk-moth, in some grouse, locusts, and several other lepidoptera, seasonally in aphids, in larval life, in some flies [**Miastor** ( ), **Chironomus** ( )] and partially or "voluntarily" when the queen-bee lays eggs which become drones.

PAEDOGENESIS

Among certain tiny flies, hardly one millimeter in length and known as **midges** (Fig. 226), there are **pupae** which produce eggs without

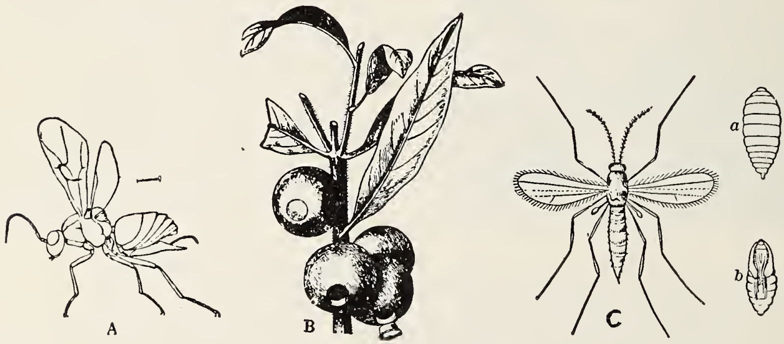


Fig. 226. Order *Hymenoptera.* D.

A, gall-fly, *Rhodiles rosoe,* female. *B,* galls produced by a bug. (A, from the Cambridge Natural History; B, from Davenport, after Kerner.)
C. Order *Diptera.* Hession fly, *Cecidomyia destructor* (one of the midges). *a,* larva. *b,* pupa. (From Davenport, after Standard Natural History.)
D. Young paedogenetic larvae of *Miastorca* genus of the family *Cecidomyiidae* in the body of the mother larva. (After Pagenstecher.)

fertilization. The larvae of the **gall-gnat,** the related members of this family, and related chironomidae likewise do this so that here we have a case of a granddaughter commencing to grow and develop not only without fertilization, but **before** the mother and grandmother themselves become full-fledged **imagoes** or adult insects.

The larvae in such cases are hatched within the parent larva and in some cases escape by the rupture of the body.

Such development of one, two, or three generations within the immature animal is called **paedogenesis** ( ).

POLYEMBRYONY

In 1904 P. Marchal described an interesting observation. He found that in two small parasitic **Hymenoptera** ( ), a **Chalcid** ( )—**Encyrtus** ( )—which lay eggs in the developing eggs of the small moth **Hyponomeuta** ( ) and a **Proctotrypid** ( )—**Polygnotus**—which infests a gall-midge—**Cecidomyid** ( )—larva, the nucleus of the egg of the insects divided, and each such particle of nucleus became a complete new embryo. A mass, or chain, of embryos is thus produced which lie in a common cyst and develop as their larval host develops. In this way over a hundred embryos may result from a single egg. Marchal pointed out the analogy of this phenomenon to the artificial polyembryony that has been induced in **Echinoderms** ( ) and other eggs by separating the **blastomeres,** and suggested that the abundant food-supply afforded by the **host-larva** may be favorable for this multiplication of embryos, which may be, in the first instance, incited by the abnormal osmotic pressure on the egg.

When many embryos develop from a single egg in the way just described, it is called **polyembryony.**

H. H. Newman has shown that in the ant-eater, **armadillo**, in which three to nine embryos commonly form in different species, all develop from a single egg. The fertilized egg does not split into separate parts but evaginates in different portions to form separate embryos.

ALTERNATION OF GENERATIONS

A true alternation of generations has been found in Hymenopterous gall flies (Fig. 226), in which a complete asexual generation (complete from egg to adult) succeeds a complete sexual generation (egg to adult), each generation being parasitic on a different host plant. The adults in each case bear no resemblance to each other; in fact, they have not only been described as different species, but actually as different genera.

EMBRYOLOGY

The flapping of wings or the "singing" of the male grasshopper attracts the "unfertilized" females. The sperm are then injected into the female receptacle, from whence they work their way into the various eggs.

The **zygote** thus formed, begins to **segment mitotically,** forming the **embryo** on **top of the yolk** close to the egg-shell. There are two protective membranes, the innermost being known as an **amnion** ( ) or **chorion** ( ), and the outer as the **serosa** ( ). As soon as the embryo has used up the yolk as food, it is ready to hatch.

However, all of this process does not take place in the body of the grasshopper. Soon after fertilization the female drills a hole in the ground with the hard portions of the ovipositor and deposits the eggs which are then covered. These hatch in the spring. It is here, in its warm underground cage, that most of the development described above takes place.

"By opening and shutting the ovipositor, a hole (Fig. 225), slightly curved, is quickly drilled in the ground. This drilling process goes on until nearly the entire abdomen is buried. Ovipositing females may frequently be found in October. A frothy matter is first laid down from the cement glands, then the eggs and cement are alternatively deposited until some 20 to 35 eggs have been laid. Each individual egg is elongated and slightly curved. The female ordinarily oviposits more than once, averaging from 100 to 150 eggs in all. The eggs are placed side by side in four rows, but standing obliquely to the wall in such a way that all slant upward. Since they are all pushed tightly against the wall of the cylindrical burrow the outside rows must project beyond the two inner rows. In this way a channel filled with frothy matter is left along the tops of the rows. Such a grooved arrangement insures the escape of the young from the lower eggs in case those in the upper ones die or are delayed in hatching.

"Each egg is covered by two membranes: (1) an outer thin, semi-

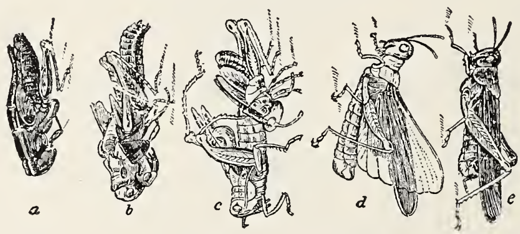


Fig. 227. *Calopt'enus Spre'tus.*

Process of acquiring wings: *a*, Pupa with skin just split on the back; *b*, the imago extending; *c*, the imago nearly out; *d*, the imago with wings expanded; *e*, the imago with all parts perfect, natural size. (After Riley.)

opaque one which under a lens may be seen to be pitted or thrown into ridges, and (2) an inner membrane **(chorion)** which is smooth and thick, but so translucent that the young insect can be seen through it after development has begun. While the outer covering is easily broken, the inner is very resistant, requiring strong pressure between the fingers to crush it.

"At hatching time in the spring the struggles of the young locust, together with the swelling of parts within the chorion, burst the latter, generally along the ventral side, and the young locust struggles out of its burrow. Once out, it rests a few minutes, generally lying on one side.

The limbs are at first limp and directed backward. The animal is still enveloped in a thin veil or pellicle which has aided it in forcing its way out of the ground. This covering shortly splits along the middle of the back and works off behind. Within an hour the locust takes its natural gray color. The foregoing account applies particularly to the Rocky Mountain locust."

The young grasshopper (like all **exoskeletonous animals**), though able to feed immediately when its normal form has been completed, cannot grow until it throws off its outer covering. This ecdysis occurs periodically. Of course, it takes time for the new skeleton to harden, so that, immediately after shedding its covering, the animal is rather soft. The wings appear after the first molt (Fig. 227). They increase in size with each molt but become **functional** only after the **final molt.** An insect which at birth resembles its parent, but is not entirely like it, as the young grasshopper, is called a **nymph** ( ).

The last molt takes place in the late summer. The nymph then "climbs up some grass stem or similar object, and, taking firm hold, often with its head pointing downward, remains motionless for several hours, till the skin swells over the head and thorax and finally splits open along a median dorsal line. From this old skin the new head, thorax, legs, wings and abdomen are slowly withdrawn while soft, expanding and hardening within half to three-quarters of an hour."

It is then a full-fledged adult and is called **imago.** After the eggs have been laid in the fall, most of the locusts die.

BEHAVIOR

As there are more different species of insects than there are of all other animals combined, it is not strange that insects should be of considerable interest and importance.

They illustrate better than any other type of animal the interrelationships and interdependence of all living things.

Pollen is carried from one plant to another by insects (Fig. 239), thus permitting vegetation to grow wherever there is sufficient heat and moisture. This makes food more plentiful. Injurious animals and pests are kept down even among their own kind. For example, the swift little **tachina fly** (Fig. 240) pokes its egg between the segments of the grasshopper's abdomen, which egg then develops into a maggot, and this maggot bores its way into the interior of its host, feeding on the living substance as it goes. It leaves the vital organs until last, so that the grasshopper does not die until the maggot has abundantly supplied itself with nourishment. Then, too, insects furnish the most abundant food for birds, worms, toads, fish, and other animals. Even man has not hesitated to use them as food. The Bible speaks of John in the desert feeding on locusts and wild honey; one itself, the insect, the other, the product of an insect.

In the markets of Manila large piles of grasshoppers with their appendages removed are offered for sale, ready for cooking. The Moors fry locusts in butter, and they are said to make a very palatable dish. In fact, many of the Indian tribes have been known to use not only grasshoppers, but ants as well, as a part of their diet. The natives of Uganda keep crickets in a warm oven for their musical sounds. In China it is said that fights are staged between crickets and that this is a favorite method of gambling.

The larva, or **grub,** of the **warble fly** is eaten by the Dog Rib Indians who are fond of caribou which in turn is thoroughly infected with these grubs. The grubs are eaten raw and the children consider them a great delicacy.

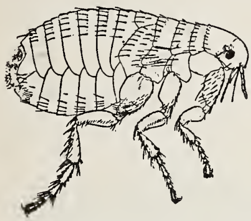
To this list may be added moths and caterpillars, eaten by both Pai Ute Indians and the Australian Bushmen, while bugs, beetles and the eggs of these insects complete the list. The Manna of the Old Testament is considered by entomologists to be the secretion, somewhat like honey, from an insect. These manna insects, now called **Gossyparia mannifers** ( ), according to Ealand, infested the smaller branches of **Tamarix gallica** ( ) in large numbers, sucked up sap in quantities, and exuded manna in the form of a sugary secretion which, in the cool of the evening, fell to the ground in solid form, but, after sunrise, melted and percolated the soil.

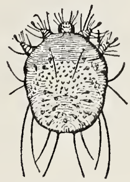
Conditions of the past have been changed since man has learned to till the soil. Insects now obtain other food and their conditions of life have changed so that comparisons of the present with ancient times when men lived under vastly different conditions, are often likely to lead one astray. The effect of changes of conditions is particularly noticeable among agricultural peoples who seldom use insects as food. In famines, anything could be relished and it was no wonder that such peoples often turned to a diet not commonly used, and then after an acquired taste had been brought about (just as it is known that practically no one likes olives the first time they are eaten, but can acquire a very considerable taste for them later) the children who had been fed upon such diet actually relished it as they grew up. No better proof of this could be found than the fact that pigeons and rabbits never normally eat meat, but, if they are fed meat alone from birth, they will die rather than eat a normal pigeon's or rabbit's food when they have become fully grown.

In addition to being used as food, insects have formed a great source from which various oils and other medicinal substances have been abstracted from time immemorial. All historical literature is filled with references to this use of insects.

Over against this beneficial use of insects may be placed the great devastations in our own country by the **periodical locusts** which sweep grain fields bare before them, and other crop-injuring pests, such as boll weevils, which injure thousands of dollars worth of cotton annually, while almost every type of grain has some sort of insect which uses such grain as its food.

As carriers of developing eggs or various immature forms of parasites, insects are now known to do great injury to man as well as to the animal world at large. The classic example is that of the **anopheles mosquito**, which carries malaria, and the **tse-tse fly**, already referred to as the carrier of the germ of sleeping sickness.





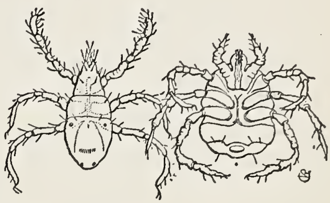
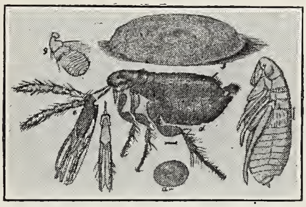


Fig. 228.
Lice—both animal and plant.

A. Female of flea, *Pulex irritans,* infesting man. (After Herms.)

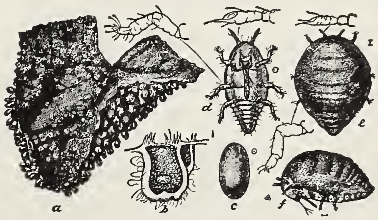
B. Sarcoptes scabei, female itch mite. (After Leuckart.)

C. Order *Acarina.* Harvestmites or "chiggers." *Leptus irritans* on the right; *L. americana* on the left. (From Osborn, after Riley.)

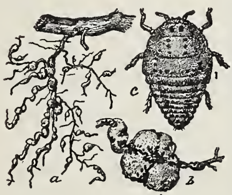


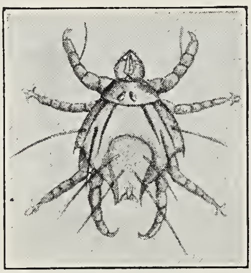
D. Common cat and dog flea *(Pulex serraticeps): a,* Eggs; *b,* larva in cocoon; *c,* pupa; *d,* adult; *e,* mouth parts of same from side; *f,* labium of same from below; *g,* antenna of same; all much enlarged. (Howard, Bull. U. S. Dept. of Agriculture, 1896.)

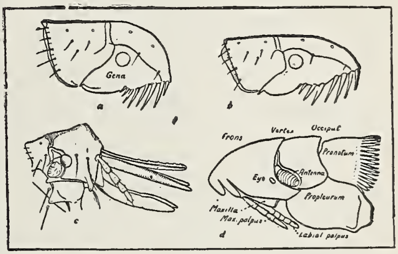
Rat Fleas.—It is believed that in tropical countries the disease germs of the bubonic plague may be transmitted from rats to men by the bites or punctures of rat fleas.



E. Phylloxera vastatrix: a, Leaf with galls; *b,* section of gall showing mother louse at center with young clustered about; *c,* egg; *d,* larva; *e,* adult female; *f,* same from side. *(a,* Natural size; *b-f,* much enlarged.) (Marlatt.)







F. Phylloxera vastatrix: a, Root-galls; *b,* enlargement of same, showing disposition of lice; *c,* a root-gall louse much enlarged. (Marlott.)

G. Pediculoides ventricosus, male. Grain louse which affects farmers and threshers. (After Braun.)

H. Head and Pronotum of *(a)* dog flea; *(b)* of cat flea; *(c)* hen flea. (After Rotschild.) *(d) Nycteridiphilus (Ishnopsyhus) hexactenus.* (After Oudemans.)

Lice (Fig. 228), and other so-called **vermin** (all of these belong to the insect group), are not only injurious to higher forms of life by their acts, but are dangerous carriers of disease.

The common house fly carries dirt and filth from the garbage can and manure pile to the food it lights upon, as well as to the baby's drinking bottle. In the filth thus deposited, there are hundreds of tiny eggs and seeds, which require only the necessary moisture and heat of the interior of the human or animal body to begin developing. This is the common way in which typhoid fever is carried. One can hardly get this disease, unless some excreted matter from a typhoid patient has been taken into the intestinal tract.

An excellent way to demonstrate the fact that insects' eggs are on our foodstuff is this: Take any fruit, such as bananas, apples, cherries, or grapes, and place the fruit in a bottle plugged with cotton, so that air, but nothing else, may pass in. In a short time, various forms of animal life will be found therein. As these forms of life hatched from eggs, the eggs must have been on the fruit before it was placed in the bottle. It is of value to note that even after one has washed the fruit well, such hatching will almost always occur. This shows how thoroughly insects fasten their eggs either on or into the surface structures of fruits.

When different kinds of crops are planted, different kinds of insects will thrive, and those alone will survive which have a sufficient food supply. Those not feeding on the new plants, either leave for more satisfactory fields or die. If it is remembered that the flesh of a duck, which feeds on fish, tastes quite different from that of one not so fed, it will be seen that the food of an animal makes a great chemical difference in the body tissues. It can then be understood how different diseases may come forth when parasites change their food and environment. If the food it eats makes a chemical difference in the flesh of an animal, it also means that, if a new chemical substance in a parasite is poisonous to man, then the same parasite, when feeding on one food, may not be poisonous and not cause disease, whereas when feeding on another type of food, such chemical poison may cause disease. Then there is the interesting fact that many diseases of birds will not affect a frog normally when such disease germs are injected, but, if the frog is placed in an incubator where its blood is kept at the same temperature as that of the bird from which the disease is taken, the disease will develop. This illustrates how different temperatures change the susceptibility of different organisms to different diseases.

The animals commonly called grasshoppers are of varying types (Fig. 229). The **true grasshopper is long-horned**; that is, it has two antennae as long or longer than its entire body. The family to which these belong is known as **Locustidae**, while the short-horned grasshoppers belong to the family **Acridiidae.**

In America the Rocky Mountain Locust is the one which does the great damage to crops. The exact time of laying and hatching eggs varies somewhat with the region of the country.

Often the young, until after the second or third molt, content themselves with feeding on whatever food is close at hand, but as soon as this food becomes scarce, the animals congregate and, as Ealand says, they march across the country in solid bodies, sometimes as much as a mile wide, "devouring every green crop and weed as they go. During cold or damp weather and at night they collect under rubbish, in stools of grass, etc., and at such times almost seem to have disappeared; but a few hours of sunshine brings them forth as voracious as ever. When, on account of the immense numbers assembled together, it becomes impossible for all to obtain green food, the unfortunate ones first clean out the underbrush and then feed upon the dead leaves and bark of timber lands, and have often been known to gnaw fences and frame buildings. Stories of their incredible appetites are legion. A friend informs the author that he still possesses a rawhide whip which they quite noticeably gnawed in a single night.

"By mathematical computation it has been shown that such a swarm could not reach a point over thirty miles from its birthplace, and as a matter of fact they have never been known to proceed over ten miles."

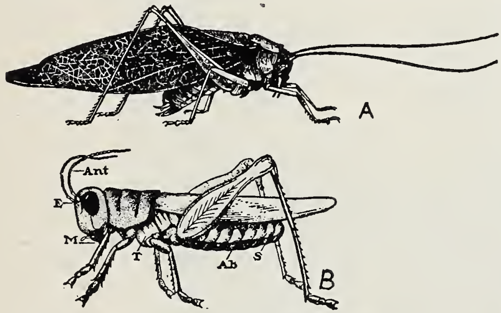


Fig. 229. Long- and Short-Horned Grasshoppers. *A.* Order Orthoptera. Katydid, *Microcentrum retinerve.* (From Sedgwick's Zoology, after Riley.) *B.* Red-legged grasshopper *(Melanoplus femur-rubrum); Ab,* abdomen; *Ant,* antennæ; *E,* eye; *M,* mouth; *T,* thorax; *S,* spiracles.

There are other species and genera which do not migrate from their native haunts. Many ingenious ways have been used to exterminate them. Certain fungus growths on plants, which the grasshopper uses for food, are fatal to him. So, too, is the little tachina fly already mentioned. In some regions, agriculturists develop such fungus growth and flies to assist in controlling the injurious insects.

The effect of a difference of temperature on insects is well illustrated by the fact that there is only one annual generation of grasshoppers in New England while there are two in Missouri.

Ditches are often dug so that the animals will fall into them, or kerosene emulsion is poured on water standing about, or placed in simple trough-like wooden movable ditches. Even if the grasshopper crawls out of the oil, it dies shortly after.

For the control of grasshoppers, see any of the books on economic entomology mentioned at the end of Chapter XXIV.

CHAPTER XXIV

THE HONEY BEE AND THE FLY

THE honey bee (Fig. 230) has been studied and written about for centuries as one of the most interesting of insects. It lives a decidedly complex social life and has lent to prophets and teachers of all times many lessons for human conduct.

The bee is intensely specialized in almost all parts of its body, and as such is of great value to any comparative study of the arthropods.

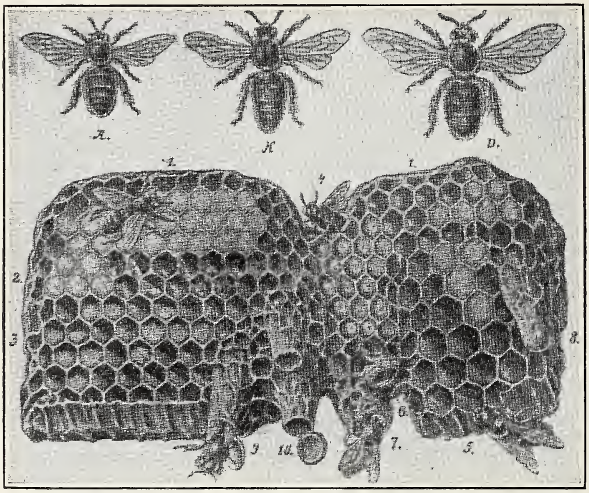


Fig. 230.

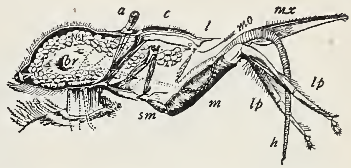
Hive bees and comb. *A*, Worker; *K*, queen; *D*, drone; 1, worker with cells filled with honey and covered; 2, cells containing eggs, larvæ, and pupæ; 3, cells containing pollen; 4, below 4 are regular cells; 5, drome cells; 6-10, queen cells. (After Schmeil.)

Foremost in rank in the hive is the queen. She is the mother of every member of the hive, for she alone, of all the inhabitants, lays eggs. With her, in the summer time, there are some sixty thousand workers and several hundred drones. The latter are killed during the winter. The abdomen of the queen is longer than that of a worker, and there is no pollen basket on the tibia of her hind legs.

The **drone** is the male. He lives upon the food gathered by the females. His body is heavy and broad, and no pollen baskets are found on the hind legs. His eyes are larger than those of either queen or worker.

The worker is an undeveloped female, which can, however, by proper food, nourishment and care, become a queen in case the old queen dies. The workers are smaller than either queen or drones. They are the ones usually seen hovering about flowers.

Bees have mouth parts (Fig. 231), modified both for biting and sucking, and two pairs of membranous wings.



B. Side view of mouth parts of the honey bee, *Apis Mellifera.* a, base of antenna; br, brain; *c*, clypeus; *h*, hypopharynx; *l*, labrum; *lp*, labial palpus; *m*, mentum; *mo*, mouth; *mx*, maxilla; *sm*, submentum. (After Cheshire.)

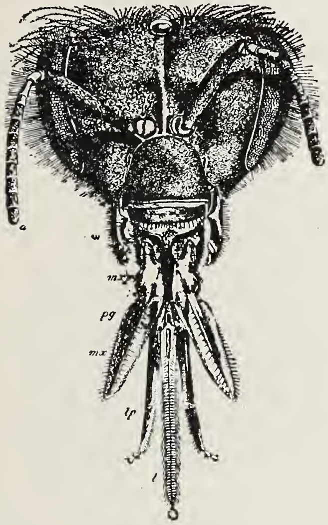


Fig. 231.

A. Front view of the head and mouth parts of a bee. *a*, Antenna; *m*, mandible; *g*, labrum and epipharynx; *mx.p.*, rudiment of maxillary palp; *mx.*, lamina of maxilla; *lp.*, labial palp; *l.*, ligula; *b.*, bouton at end. The paraglossæ lie concealed between the basal portions of the labial palps and the ligula. (After Cheshire.)

C. Tongue of honey bee. *p.*, protecting bristles; *s.*, terminal spoon; *t.*, taste setae. (After Will.)

EXTERNAL APPEARANCE

The body is divided into head, thorax, and abdomen. (Fig. 213.) The body is covered with a skin or cuticle which is composed of a thin chitinous layer produced by the secretion from the cells lying beneath it. This serves as a protection, but it is cast off at various intervals during the early stages of growth.

There are a pair of **large compound eyes** and three **ocelli or simple eyes.** The arrangement of the ocelli are somewhat different in queen, worker, and drone. Two feelers **(antennae)** project from the front of the head.

The mouth is made up of an upper lip or **labrum**, an **epipharynx,** a **pair of mandibles, two maxillae,** and a **labium.** This last mentioned is the under lip.

The labrum is joined to the **clypeus** (the dome-shaped portion of the skull), (Figs. 217 and 231), lying just above it. The **epipharynx** is the fleshy projection extending beneath the labrum. It serves as an organ of taste. The jaws, or mandibles, lie on each side of the labrum, being notched in the queen and drone, and smooth in the worker.

The **labium** lies medially and extends downward from beneath the labrum and is quite complicated. The **sub-mentum**, which is triangular in shape, joins the labium to the back of the head. The **mentum** lies next to the sub-mentum. The mentum is chitinous and contains muscle. The tongue, or **ligula,** lies immediately beyond the mentum. The tongue has a spoon-shaped end known as a **bouton.** A **labial palpus** lies at each side of the tongue, while tiny hairs, used as organs of taste and touch, as well as for gathering nectar, are arranged in regular rows upon it.

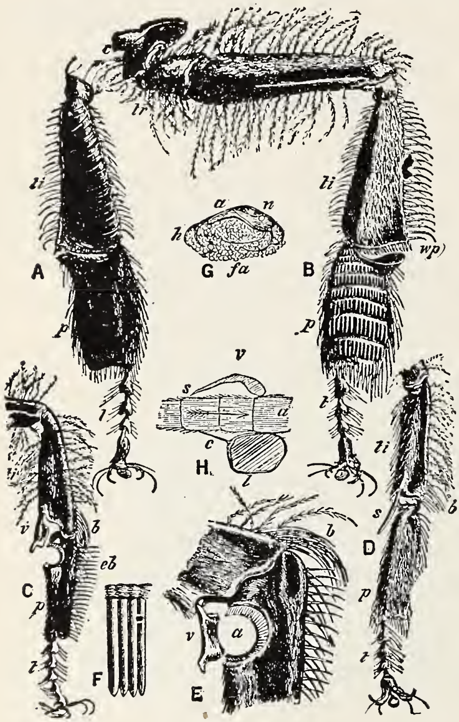


Fig. 232.

Legs of worker honey-bee. *A.*, outer side of metathoracic leg; *p.*, metatarsus; *t.*, tarsus; *ti.*, tibia. *B.*, inner side of metathoracic leg. *c.*, coxa; *p.*, metatarsus; *t.*, tarsus; *ti.*, tibia; *tr.*, trochanter; *wp.*, wax pinchers. *C*, prothoracic leg. *b.*, pollen brush; *eb.*, eye brush; *p.*, metatarsus; *t*, tarsus; *ti*, tibia; *v.*, velum. *D.*, mesothoracic leg; lettering as in *C*. *s.*, pollen spur. *E.*, joint of prothoracic leg; lettering as in *C*. *F.*, teeth of antenna comb. *G.*, transverse section of tibia through pollen basket. *fa.*, pollen; *h.*, holding hairs; *n*, nerve. *H.*, antenna in process of cleaning. *a.*, antenna; *s.*, antenna comb; *l.*, section of leg; *s.*, scraping edge of *v.*, velum. (From Root, after Cheshire.)

The lower jaws or maxillae extend over the mentum on both sides. There are stiff hairs on their edges, and **maxillary palpi** on each side.

The thorax is divided into **prothorax, mesothorax,** and **metathorax** (Fig. 213), the last two divisions each supporting a pair of wings, while hairs, which are used in gathering pollen, cover the outside of the entire thorax.

The legs of the bee are highly specialized (Fig. 232). The **prothoracic legs** have both femur and tibia covered with **branched hairs** which are used in gathering pollen. A **pollen brush** made up of curved bristles is seen at the distal end on one side of the tibia. This brush is used to brush up the pollen which has been loosened by some of the coarser spines.

On the other side of the tibia, a flat movable spine, known as the **velum,** fits over a curved indentation in the first tarsal joint. The whole structure, brush and velum, is known as the **antenna cleaner,** while the row of teeth lining the indentation is called the **antenna comb.**

The antennae are cleaned by being pulled through the indentation between the teeth and the edge of the velum.

On this first tarsal joint also, there is found a row of spines called the **eye brush.** This structure is used to brush out pollen which has lodged about the compound eyes.

On the last tarsal joint of each leg there is a pair of notched claws by which the insect holds on to rough surfaces. Between these claws there is a fleshy glandular **lobule,** known as the **pulvillus,** which is covered with a sticky secretion from the glands. It is by this sticky substance that the insect can attach itself to smooth surfaces. Then, too, **tactile** or touch hairs are present.

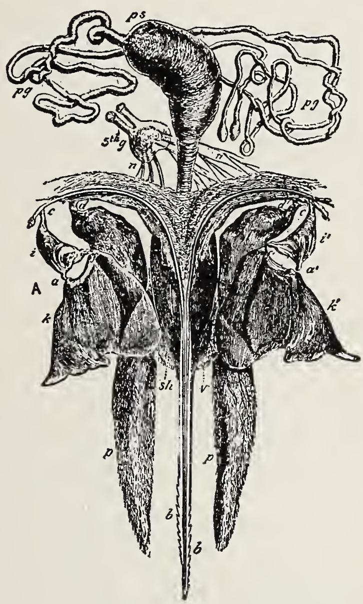


Fig. 233.

Sting of worker honey-bee. *b.*, barbs on darts; *i.*, *k.*, *l.*, levers to move darts; *n.*, nerves; *p.*, sting-feeler; *pg.*, poison gland; *ps.*, poison sac; *sh.*, sheath; *5th g.*, fifth abdominal ganglion. (From Packard, after Cheshire.)

The **mesothoracic legs** do not have an antennae cleaner, but at the distal end of the tibia there is a **spur** which is used to pry the pollen out of the pollen baskets on the third pair of legs, as well as to clean the wings.

The **metathoracic legs** are probably the most interesting, in that they possess a **pollen basket,** a **wax pincer,** and **pollen combs.** The pollen basket is a concavity in the outer surface of the tibia. There are rows of curved bristles along the edges. Pollen is stored in this basket. The filling takes place by the pollen combs scraping out the pollen from the hairs on the thorax into the basket on the opposite leg.

Because of their pincer-like appearance the opposed ends of the tibia and metatarsus of the hind leg were formerly called "wax-pincers." The row of wide spines on the end of the tibia forms the **pecten;** the flat, tamp-like plate at the end of the metatarsus opposed to the pecten, is the **auricle.** This jaw-like structure is used to transfer pollen to the pollen-basket. The pecten is scraped downward over the pollen comb of the opposite leg, and the pollen thus secured is pushed upward into the pollen-basket from below by the rising auricle as the leg is flexed.

As already stated, a pair of membranous wings are attached to the **mesothorax** and a pair are attached to the **metathorax.** There are **hollow ribs,** called **nerves** or **veins,** passing through each wing. Often a row of little **hooklets** on the anterior margin of the hind wing is inserted into a trough-like fold in the posterior margin of the fore wing and thus joins them together.

The abdomen is made up of six segments, each segment consisting of a **tergum or dorsal plate,** and **sternum or ventral plate.** A pair of **wax glands** is located on each of the four hindermost sternal plates. Both queen and worker possess a **sting** (Fig. 233) at the end of the abdomen, while the drone possesses a copulatory organ instead. There are also slit-like openings of the reproductive system and an anal opening in queen and worker.

The sting has a pair of **sting feelers** by which the bee seems to choose a favorable location for the deposit of the sting. Two barbed **darts** are then sent out. There is a **sheath** which guides the darts and aids in conducting the poison. The poison is secreted by a pair of glands, one acid and one alkaline, and it is then stored in a **reservoir.** It is commonly believed that if a bee stings it dies. This is not necessarily true; but, very often a part of the intestine and the poison glands are pulled out of the body with the sting, and then, of course, the insect cannot live.

Queens usually do not sting except in combat with other queens.

INTERNAL ANATOMY AND PHYSIOLOGY

THE DIGESTIVE SYSTEM

Beginning at the anterior end, the digestive system (Fig. 234), is made up of **mouth, oesophagus or gullet, honey-sac or honey-stomach, true stomach, small intestine or ileum,** and **large intestine or colon.**

The oesophagus passes through the thorax and is expanded into a honey-sac at the anterior end of the abdomen. A **stomach-mouth** with four triangular lips is found at the posterior portion of the honey-sac. A number of bristles extends backward from the top of the lips. If the alimentary canal be placed in a one-half of one per cent salt solution immediately after the bee is killed, these lips will open and close for about thirty minutes. Both circular and longitudinal muscles surround the lips.

The glands in the walls of the stomach secrete digestive juices which change the food into chyme. Part of this is absorbed and part forced back into the ileum by muscular contractions. Here undigested food is dissolved and also absorbed, while that which is not digested is thrown into the colon, and from there, out of the body. No faeces are deposited in the hive if bees are kept in proper condition.

Two pairs of salivary glands may be found: one pair within the head lying against the cranium, and one pair in the ventral portion of the anterior half of the thorax. The substances secreted from these glands are weakly alkaline and are poured out upon the labium. Here they act on the food as it is ingested.

THE CIRCULATORY SYSTEM

The blood of the honey bee is quite like that of the crayfish and grasshopper in being colorless and containing amoeboid corpuscles. The amount of oxygen it contains is not very great. A "respiratory pigment"—hemocyanin, a copper compound, gives the blood a faintly bluish color, which is especially perceptible when some dozen or more drops of blood are obtained. The blood acts as an aid in the fixation and distribution of oxygen.

The crayfish is also like the bee in that it has **a dorsal blood vessel and many sinuses,** but the bee's circulatory system is even less complete than that of the crayfish.

The **heart, or dorsal vessel,** is a tube in the median dorsal region just below the surface, closed posteriorly and open in the head-region. The walls are muscular and the heart contracts at intervals.

The blood itself enters through **five pairs of ostia,** one into each of the five compartments into which the heart is divided. Each compartment is called a **ventricle.** Each contraction sends the blood toward the heart. There are valves which prevent it from flowing backward. It then passes through the various spaces in the body to bathe the tissues. As the blood passes ventrally, it is gathered into the **pericardial sinus,** and, when the muscles surrounding this sinus contract, the blood is forced through the ostia back into the heart.

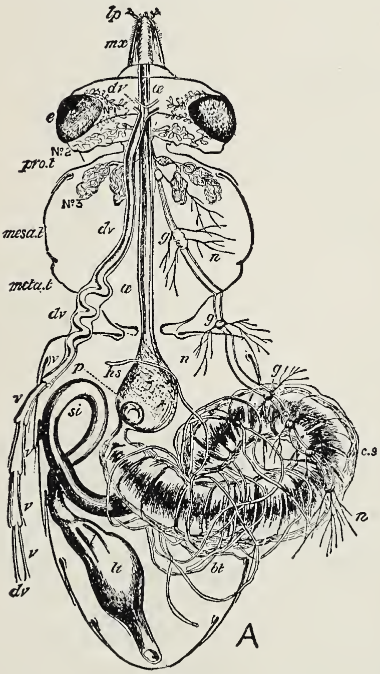
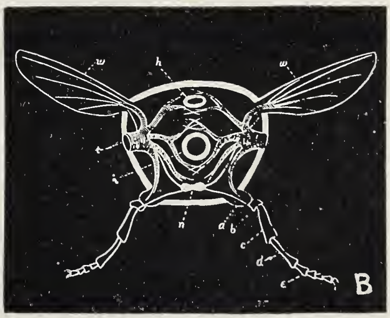


Fig. 234.

A. Internal organs of the honey-bee. *bt.*, malpighian tubules; *c.s.*, true stomach; *dv.*, dorsal vessel; *e.*, eye; *g.*, ganglia of nerve chain; *hs.*, honey sac; *li.*, rectum; *lp.*, labial palpus; mesa. *t.*, mesothorax; meta, *t.*, metathorax; *mx.*, maxilla; *n.*, nerves. No. 1, No. 2, No. 3, salivary glands; *oe.*, oesophagus; *p.*, stomach mouth; *pro.t.*, prothorax; *si.*, small intestine (ileum); *v.*, ventricles of dorsal vessel.



B. Ideal transverse section of an insect. *h.*, dorsal vessel; *i.*, intestine; *n.*, ventral nerve-cord; *t.t.*, stigmata leading into the branched tracheal tubes; *w.w.*, wings; *a.*, coxa of one leg; *b.*, trochanter; *c.*, femur; *d.*, tibia; *e.*, tarsus. (After Packard, A, from Cheshire.)

THE RESPIRATORY SYSTEM

Along each side of certain thoracic and abdominal segments there appear openings called **spiracles** (Fig. 215). It is through these openings that the bee breathes. One pair of these spiracles may be found in the prothorax, one pair in the metathorax, and five pairs in the abdomen.

The spiracles open into little tubes known as **tracheae** which unite in turn with other tubes running in a longitudinal manner. These longitudinal tubes are called **the trunks,** and from the trunks many branches are given off to all parts of the body. The tracheary tubes (though only one cell in thickness) have thickened rings arranged spirally, and it is these rings which keep the tubes open.

Air-sacs are found in the abdominal region. These are expanded portions of the tracheae and probably make the bee lighter as it flies, for the bees can apparently increase and decrease the size of the air-sacs at will. There are tiny valves in the spiracles and the bee takes in and expels air by expansions and contractions of its abdomen. Hairs surround the spiracles so as to prevent dust from entering. The rate of respiration increases with the fatigue of the insect. Air is carried directly to the tissues through the tracheae so that there is no need for a lung system in which blood and oxygen must mix.

THE EXCRETORY SYSTEM

There are **Malpighian or urinary tubules** (Fig. 234, A) which are long, fine, hair-like structures, opening into the anterior end of the intestine. These are the excretory organs. Excretions are taken from the blood in the form of urates, and pass through these urinary tubules to the intestine from whence they are thrown out of the body with the faeces.

THE NERVOUS SYSTEM

The nervous system (Fig. 214, 235) of the bee is made up of a **chain of paired ganglia** with **two groups of smaller ganglia.** The first are called the **stomatogastric** and the latter the **sympathetic** ganglia, respectively. These ganglia are made up in turn of the following masses of nerve tissue: two in the head, two in the thorax, and five in the abdomen.

Each mass is composed of two ganglia which lie side by side, and these ganglia are connected with the mass in front and behind by two **nerve cords.** Only the brain (the most anterior pair of ganglia), also called the **supraoesophageal ganglia,** lies dorsal to the digestive tract.

The compound eyes, **the ocelli,** the antennae, and the labrum, are connected with the brain by nerve twigs, while the mandibles, labium, and other mouth-parts are connected with the **suboesophageal ganglion** lying directly beneath the oesophagus.

The most anterior ganglia in the thorax innervate the muscles of the first pair of legs, while the posterior thoracic ganglion is larger and composed of several ganglia which have grown together. From the fore part of this latter ganglion, nerves run to the fore wings and middle pair of legs, while twigs from the posterior portion of this same ganglion pass to the hind wings and legs.

The organs and walls of the abdominal region are supplied by twigs from the various abdominal ganglia; but, as with most animals, the more posterior abdominal ganglia are the larger.

The stomatogastric portion of the nervous system is composed of

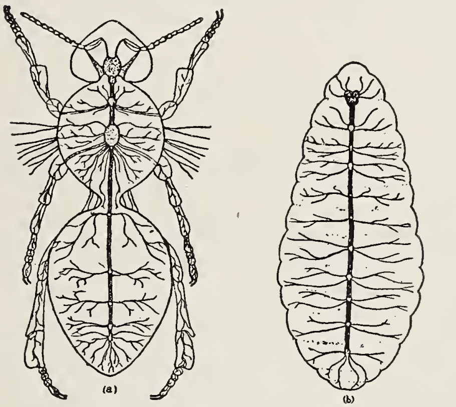
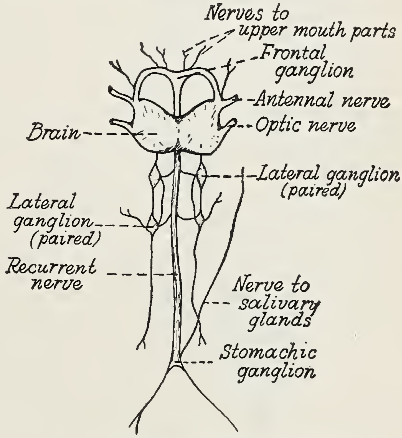
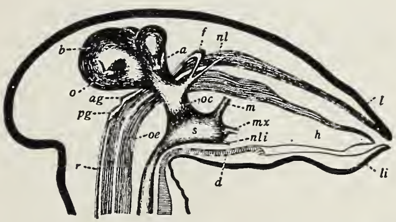


Fig. 235.

A. Nervous system of honey-bee, at *a.*, and of its larva, at *b.*, showing the simple type of the larva and the specialization in the adult due to fusion of the ganglia. (From Sanderson and Jackson, "Elementary Entomology," by permission of Ginn & Co.)



B. Sympathetic nervous system of an insect, diagrammatically represented. (After Kolbe.)



C. Nervous system of the head of cockroach. *a.*, antennal nerve; *ag.*, anterior lateral ganglion of sympathetic system; *b*, brain; *d.*, salivary duct; *f.*, frontal ganglion; *h.*, hypopharynx; *l.*, labrum; *li.*, labium; *m.*, mandibular nerve; *mx.*, maxillary nerve; *nl.*, nerve to labrum; *nli.*, nerve to labium; *o.*, optic nerve; *oc.*, oesophageal commissure; *oe.*, oesophagus; *pg.*, posterior lateral ganglion of sympathetic nervous system; *r.*, recurrent nerve of sympathetic system; *s.*, suboesophageal ganglion. (After Hofer.)

many small ganglia which are in direct connection with the organs of digestion, circulation, and respiration, while the sympathetic nervous system is made up of the many fibers which pass to all parts of the body from the triangular ganglia lying in each segment.

ORGANS OF SPECIAL SENSE

These have already been discussed very thoroughly under the general term, "The Senses of Insects," in Chapter XXIII.

THE MUSCULAR SYSTEM

As in the crayfish, the muscles of the honey bee are attached to the inner walls of the body. The number of muscles is very large. The largest muscles are those which move the wings and legs.

Muscles are both voluntary and involuntary. A good example of the latter has already been noted in the experiment suggested of placing a portion of the intestine in a one-half of one per cent salt solution when the lips of the stomach-mouth will open and close for some time.

Insects usually have much greater muscular strength proportionately than larger animals. This is accounted for by the fact that the weight of muscle increases as the cube of its diameter, while its strength increases only as the square of its diameter.

THE REPRODUCTIVE SYSTEM

Only the queen (Fig. 236, A) can lay eggs, although the workers have rudimentary ovaries.

The **two ovaries** almost fill the abdomen of the queen. Each of the ovaries is made up of a great number of **ovarian tubules** which contain eggs of different sizes. The eggs pass into the **oviduct** from the tubules, thence into the vagina and out of the body through the **genital aperture.**

There is an opening into the vagina which connects with the **spermatheca,** or sac, in which the sperm are stored, and sperm from this sac may apparently be released at will by the queen as the eggs pass through. If the sperm is not released, the egg is not fertilized and then drones hatch. Only females hatch from fertilized eggs.

In the drone (Fig. 236, B) there are **two testes** made up of several hundred **spermatic tubules** in which the sperm are formed. A pair of fine tubes, called **vasa deferentia,** connect these spermatic tubes with the **seminal vesicles.** These latter

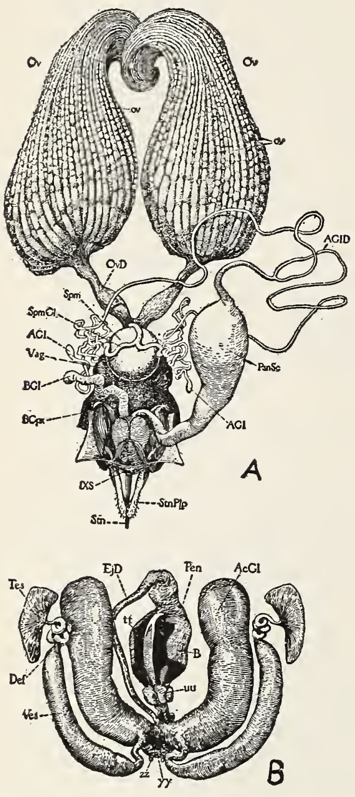


Fig. 236.

A. Reproductive organs, sting, and poison gland of queen honey-bee. *AGl.*, acid gland; *AGlD.*, duct of acid gland; *BGl.*, alkaline gland; *Ov.*, ovary; *ov.*, ovarian tubules; *OvD.*, oviduct; *Psn.-Sc.*, poison sac; *Spm.*, spermatheca; *Stn.*, sting; *StnPlp.*, sting feeler; *Vag.*, vagina.

B. Reproductive organs of drone bee, dorsal view, natural position. *AcGl.*, accessory gland; *B.*, bulb of penis; *EjD.*, ejaculatory duct; *Pen*, penis; *Tes.*, testis; *vDef.*, vas deferens; *Ves.*, seminal vesicle; *tt.*, *uu.*, *yy.*, *zz.*, parts of penis. (From Snodgrass, Tech. Series, 18, Bur. Ent., U. S. Dep't of Agric.)

in turn open into a pair of large mucous glands which unite. It is at this union that the **ejaculatory duct** begins. This duct ends in the copulatory organ.

The sperm of the male are placed in the **spermatheca** (seminal receptaculum) of the queen by a single drone, where they remain alive for many years, in fact as long as the queen lives and lays eggs. While the average life of a queen is probably from three to four years, there is on record a queen which continued laying fertile eggs for thirteen and a half years.

About five to eight days after emerging from the comb-cell, a queen leaves the hive. First, she crawls about and takes very short flights, and then goes on a **nuptial trip** of about thirty minutes. One of the drones copulates with her during the nuptial trip, after which the queen returns to the hive.

The eggs are bluish-white and oblong in shape. They are fertilized just before leaving the queen's body. The eggs are deposited at the base of the cells and then fastened into position in the cells by a secretion. Fertilized eggs are laid in cells that have already been arranged to receive them, some being in **queen cells**, and some in **worker cells**, while unfertilized eggs are placed in **drone cells**. But there seems to be evidence that mistakes are made, and the right type of egg is not always placed in the right cell.

EMBRYOLOGY

After the nuclei of the sperm and egg have united into a single nucleus, a chitinous covering, **the chorion**, surrounds the entire egg. As cleavage takes place, no definite cell walls appear. This means that a great mass of protoplasm is present with many nuclei. These nuclei migrate to the periphery to form a single layer of cells, called the **blastoderm**, while the remaining portion of the yolk remains as yolk-substance until it is converted either into food for the developing embryo, or into further cellular substance.

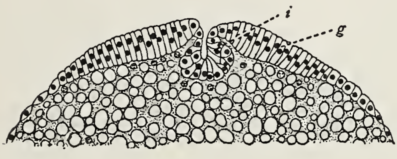


Fig. 237.

Cross section of germ-band of *Clytra* at gastrulation. *g.*, germ-band; *i.*, inner layer. (After Le'caillon.)

A **germ-band** or **primitive streak** (Fig. 237) now forms on one side of the egg where the blastoderm becomes thickened. This is to become the ventral side of the bee. The brain develops separately. A median groove arises in the germ-band, and so two germ layers are formed, an outer layer called the **ectoderm**, and an inner known as the **entomesoderm**. It is the latter layer from which both entoderm and mesoderm arise. The germ-band then grows around the entire egg.

It is of interest to know that, while the antennae and four pair of appendages can be seen near the anterior end of the embryo, one pair of the anterior appendages disappear and the others become mouth parts. Then, three pair of appendages develop on the thorax, all of which disappear before hatching.

METAMORPHOSIS

The life-history of the bee is divided into four periods: **egg, larva, pupa,** and **adult or imago.**

Queens, workers, and drones remain in the egg three days, but the queens remain in the larval stage five and a half days, and in the pupal stage seven days, while the workers remain in the larval stage five days, and in the pupal stage thirteen. The drones remain in the larval stage six days, and in the pupal stage fifteen days.

During the fourth day the larva hatches from the egg as a white, footless, soft, grub-like form floating in "bee-milk" (also called "royal jelly"). This "milk" is composed of digested honey and pollen with probably some glandular secretions. The "milk" is formed in the true stomachs of special "nurse" workers who place it in the cells.

All larvae are fed this royal jelly for about three days by the nurse workers, after which a change takes place. Those which are to become workers are fed honey and digested pollen, while those which are to become queens alone continue to get the richer royal jelly until they change to the pupal stage. The drone larvae, after the fourth day, receive undigested pollen and honey.

The young larvae grow rapidly and shed their exoskeleton several times. In fact, during the last molt, even the lining of the alimentary canal and all its contents are shed with the exoskeleton.

Some five or six days after hatching, the nurse worker places a quantity of food in the cell with the larva and places a cap on the cell. The larva spins a cocoon of silk about itself some two or three days later. It is now in a resting stage and is called the **pupa.**

The spinning-glands are in the mouth region, and later become the salivary glands of the adult.

Almost the entire structure is made over during this pupal stage, and the full-fledged bee emerges in its adult form and shape.

BEHAVIOR

As the queen emerges from the pupal stage the eggs have not yet distended her abdomen. She is, therefore, about the same size as a worker. As soon as she becomes accustomed to her surroundings, she starts on a hunt for other queen cells. She breaks through these and stings the pupa within or tears the cell down and lets the workers remove such destroyed structures with the other debris. There is thus only one queen left. It is after this time that the nuptial-flight, already mentioned, takes place. By the ninth or tenth day she is busy laying eggs. The number of eggs laid, or at least the rapidity with which eggs are laid, is determined by the amount of food the workers bring home. More eggs are laid when more food is obtained.

The workers, when young, act as nurse maids for a week or two before taking up the regular duties of gathering food. Some of these also defend the hive against outside attacks, clean the hive, and even go scouting to find suitable new quarters before swarming.

The workers really work themselves to death, and probably live only some five or six weeks. New ones are being hatched continually to keep the normal number of bees in the hive. Those which hatch in the fall may live five or six months.

If a queen should die, any one of the workers may with proper feeding, be able to develop and lay eggs, but in such cases the new queen would not have had the nuptial-flight, and therefore no eggs would be fertile. Consequently drones alone are hatched from the eggs.

Drones hatch in the same way that queens and workers do, but take no part in the work of the hive. One of them alone acts as queen-consort. As soon as food is scarce, they are starved to death and their dead bodies are removed with the remaining debris. At such a time even the drone pupae, larvae, and eggs are destroyed.

As new bees are constantly being hatched, the hive may become overcrowded. When this occurs, it is the old queen which collects several thousands bees about her and goes through a complicated preparation to start a new colony. Scouts are sent out to seek a fitting location, and after first settling on a tree-branch or other object in a very dense cluster, the whole colony takes up its new abode.

The cells in the hive are made of wax. Those which are to have eggs placed in them, are hexagonal in shape, although a careful examination will show they all vary slightly from one another. The cells which are to contain honey, are rounded.

The wax is produced by a secretion from the smooth paired patches on the ventral surface of the abdominal metameres, called **wax-glands.** The process gone through is as follows: The bees gorge themselves with honey. Great clusters of such bees then hang from the top of the hive for several hours, and thin scales of wax form on the plates. These scales of wax are then removed by the hind legs, while the fore-legs transport the wax to the mouth. Here the wax scales are mixed with saliva and kneaded by the mandibles. The wax is then ready either to repair old cells or build new ones.

The cells may be built especially for honey or for breeding, but often drone cells, even when the cocoon is still present, are used for honey cells. However, cells made especially for honey have the openings somewhat above their bases so that the honey will not run out

The cells which fasten the comb to the top and sides of the hive are called **attachment cells.**

Bees gather **nectar** (not honey) from flowers. The maxillae and the labial palpi form a tube through which the tongue can move backward and forward. As the epipharynx is lowered, a definite passage connects this tube with the oesophagus. The nectar itself becomes attached to the hairs on the tongue, and is forced upward by pressing maxillae and palpi together. It is then swallowed into the honey-sac where the necessary chemical changes, which convert it into honey, take place. Here it is retained until the bee reaches the hive, when it is regurgitated into the cells made to receive it. As there is much water in newly-formed honey, the cells are left open until the water is considerably evaporated. This is called the "ripening process." When the honey is "ripe" the cell is capped with wax.

The bees keep their wings moving while in the hive both to keep air circulating and (in winter) to produce heat.

About thirty to fifty pounds of honey are produced a season by one hive if conditions are favorable.

As honey lacks proteins, bees gather pollen by means of their mouth parts and legs, and mix it with either saliva or even nectar to make it sticky. It is then placed by the hind legs in the pollen baskets. As the bee enters the hive, it backs up to a cell in which a larva is placed, and scrapes the pollen into such cell by aid of the **spur** already mentioned. The deposited substance is known as "bee-bread." The young workers then pack this bee-bread into the cells by using their heads as tampers.

Still another substance, known as **propolis** or **"bee-glue,"** is gathered by bees for the purpose of filling up cracks, for strengthening weak parts, or even, probably, as a sort of varnish. Propolis is merely the resinous material gathered from various plants which is then inserted into the pollen basket. When propolis is brought to the hive by a worker, another worker removes it from the gatherer. It is this other worker which also applies it where needed.

In warm, dry weather water is often sucked into the honey-sac from dew, brooks, or ponds, and then carried to the larvae in the hive. In cool weather enough water usually condenses in the hive. In fact, so much moisture may condense as to injure the occupants.

All debris is removed immediately so that cleanliness is always insured.

ENEMIES OF THE HONEY BEE

There is a bee-moth, **Galleria mellonella**, which, when it can find an entry, lays its eggs in the hive. The larvae then feed on pollen, cocoons, and even cast-off larval skins. They burrow into the comb and line their burrow with a silk which protects them from the bees, much as a spider's web can either keep out or entrap insects.

There are also bee-lice which attach themselves to the queen and weaken her by sucking the juices from her body. The bee-lice, while common along the Mediterranean Sea, are uncommon in America. Spiders often catch bees in their webs.

Other insects such as dragon-flies, ants, and wasps may attack bees. Toads and lizards also attack them, but these latter can be removed to some distance from the hive and will then serve the important function of devouring really noxious insects.

Mice prey upon pollen, honey, and even bees in the winter time. One may note here, as we have already noted in the discussion of the relation of insects to man, that there may be various ways of insuring a "balance in nature." As cats devour mice, and mice bees, the number of cats may be the deciding factor of the number of bees there are in a given neighborhood. In fact, Huxley even suggested that this idea could be carried still further by considering the number of old maids who were fond of cats, these cat lovers then becoming the deciding factor as to the number of bees a given region might have.

Various diseases also afflict bees. These are probably largely of a bacterial nature brought about by too long confinement in the hive. Once a disease has taken hold of a hive, it may infect any or all other hives in the region.

GYNANDROMORPHS

It has been found that among butterflies, ants, and bees, it is not uncommon to have an abnormal individual which has male characteristics in one part of its body and female characteristics in another. The term **gynandromorphs** (Fig.

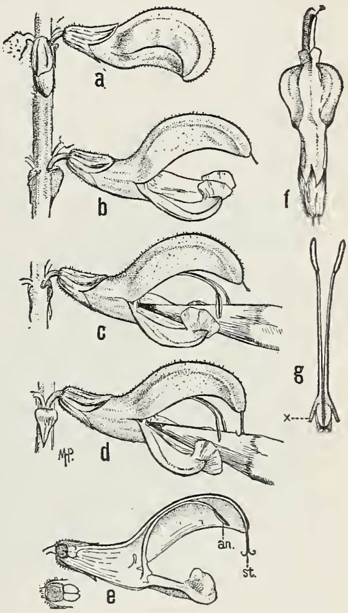


Fig. 239.

Salvia sp. (One of the Labiatæ.) *a.*, flower bud; *b-f.*, various views of the open flower; *an.*, anther; *st.*, stigma; *x.*, projections near the base of the filaments. The lead pencil is made to imitate an insect visiting the flower for pollen. By pressure at the base of the filaments, the anthers are brought into contact with the surface of the pencil, which thus becomes covered with pollen. When the next flower is visited the stigma, having then bent down and spread apart, receives the pollen from the other flower. Thus is accomplished cross-pollination. In *b.*, before the visit of the insect, the stigmatic surfaces are still in contact, so that pollination is not possible. (From C. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Son & Co., Publishers.)

Fig. 238.

External appearance of gynandromorph. Lateral hermaphroditism of gypsy moth. Left side female; right side male. (After Taschenberg.)

238) has been given such individuals. The more common form such gynandromorphs assume is that the anterior part of the body may be one type and the posterior another, or the entire right side may be of one sex and the entire left side of another.

CROSS FERTILIZATION OF PLANTS BY BEES

Bees are particularly valuable in bringing about cross fertilization of flowers. In fact, the **bumble bee** is about the only insect visiting red clover, which has its mouth parts long enough to reach down for the nectar of that plant, so that if it were not for the bumble bee, red clover would probably not grow at all.

Orchards which have hives of bees usually show a better harvest of fruit than those without hives.

It is probably color, odor, and the structure of both insect and plant which determine which plants are visited most.

Many plants are so constructed that an insect entering the flower for nectar comes in contact with the pollen of the plant which thus brushes off on the insect's back (Fig. 239). Then as another flower is visited this pollen is brushed off by the stigma thus bringing about fertilization.

CLASSIFICATION

The summary of the Arthropoda will show under what phylum, class and order bees are classified. But here it is necessary to mention the following five types of honey bees found in the United States, though none are native.

German, with black-colored abdomen. These are the so-called wild honey bees.

Italian, with yellow-striped abdomen.

Carniolan, with gray abdomen.

Cyprian, with yellow abdomen.

Caucasian, with yellow-gray abdomen.

All bees are included in the great family **Apidae**, but there are both solitary and social species. Then, too, some are miners, carpenters, leaf-cutters, etc.

As different species of bees have different length of tongues, their food must vary accordingly. This was seen in our discussion of the bumble bee, which alone of all the bees, has a long enough tongue to obtain the nectar from red clover. Short-tongued bees must seek a flower with a less deeply placed nectar.

THE FLY

As flies may carry "tuberculosis, cholera, enteritis (including epidemic dysentery and cholera infantum—the fly-time 'summer complaint' of infants), spinal meningitis, bubonic plague, smallpox, leprosy, syphilis, gonorrhea, ophthalmia, and the eggs of tapeworms, hookworm, and a number of other parasitic worms," they are certainly worthy of our attention, and should be considered here, although it must not be thought that flies are the only carriers of these diseases. It is especially interesting to know that, while only about two persons die each year in the United States from the bites of poisonous snakes and about one hundred from the bites of rabid dogs, nearly 100,000 die annually from diseases carried by flies.

There are more than 43,000 different kinds of flies, gnats and mosquitoes which have been described in entomological literature, and there is no telling how many more are still unknown. **Tachina flies** (Fig. 240), already described as killing grasshoppers, and **Syrphus flies** (   ) which feed on insects are of real value to man, but nearly all others should be exterminated.[1] Over ninety per cent of the flies found in and about homes are the regular typhoid flies. When

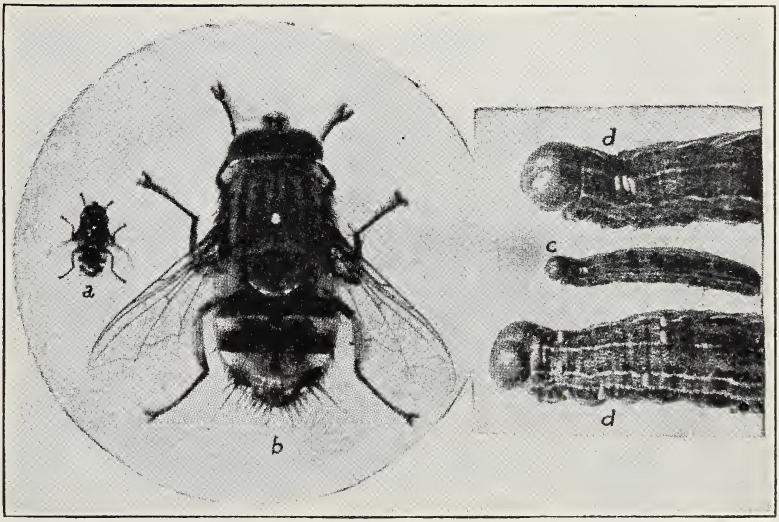


Fig. 240.

The Friend of Farmers. Red-tailed tachina-fly *(Winthemia 4-pustulata.) a.,* natural size; *b.,* much enlarged; *c.,* army worm on which fly has laid eggs, natural size; *d.,* same, much enlarged. (After S. Singerland.)

it is remembered that the feet of these are furnished with claws for climbing over rough surfaces as well as with two pads, the **pulvilli**, covered with sticky, tubular hairs by which the animal can attach itself to ceilings and glass surfaces, one can understand the excellent summing up of what this means—that "No more effective mechanisms for collecting dust could be designed than a fly's feet and proboscis (Fig. 216),

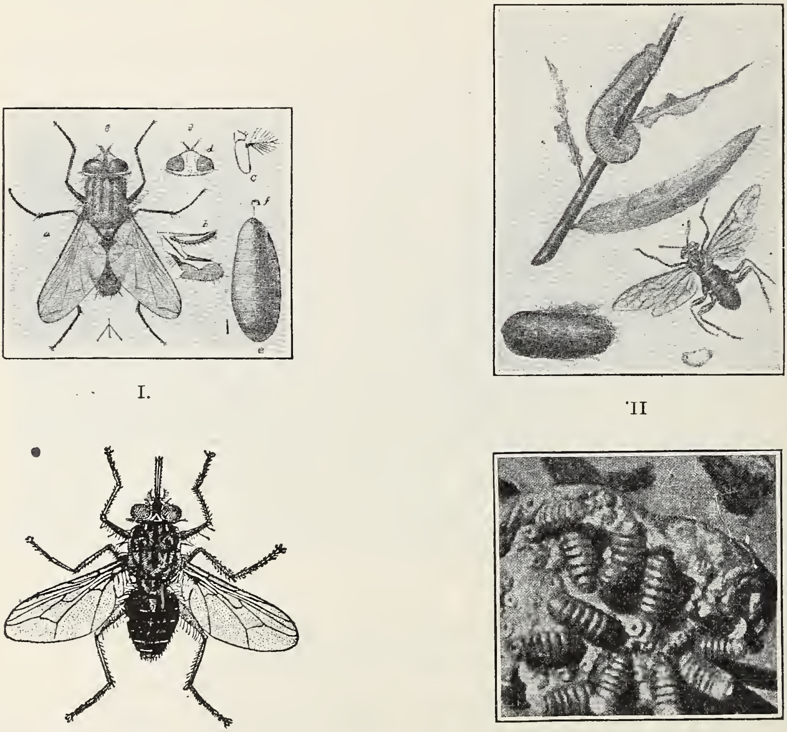
[1]In the early part of 1923 hundreds of thousands of dollars were lost in the Santa Clara Valley, California, by the larvae of Syrphus flies which could not be washed off the spinach leaves, thus necessitating the closing of the canneries. Even friendly insects sometimes do much damage.

a combination of six feather dusters and thirteen damp sponges. While the constant 'cleaning' movements of flies are clearly designed to rub off and scatter the adhering germs everywhere they go."

There are "little house flies" **(Fannia canicularis)** which probably most people believe grow into the regular house flies. Their breeding habits and feeding places are quite similar to house flies, **but,** as **flies hatch in the adult form they do not grow after once becoming flies.**

Other flies, such as **bluebottles, greenbottles,** and **flesh flies** or **blowflies,** are also found about the home and frequently lay their eggs on meat. These flies are scavengers.

In the south there is the screw-worm fly **(Chrysomyia macellaria)** which deposits its eggs on wounds, for the maggots of this species feed on living flesh. It is these flies also which are likely to lay their eggs in the nostrils and ears of children or even of adults as they sleep out of



I. II. III. IV.

Fig. 241.

I. Typhoid fever or house-fly *(Musca domestica)*. *a,* Adult male; *b.,* proboscis and palpus of same; *c.,* terminal joints of antennæ; *d.,* head of female; *e.,* puparium; *f.,* anterior spiracle; all enlarged. (Howard and Marlatt, Bull. U. S. Dept. of Agriculture, 1896.)
II. Metamorphosis of Saw-Fly.
III. Tsetse fly, which causes a disease of cattle in Africa, enlarged. (L. O. Howard.)
IV. Larvæ of bot flies attached to the walls of the stomach of a horse. (After Osborn.)

doors. The maggots then cause intense pain as they feed on the surrounding flesh.

The stable fly **(Stomoxys calcitrans)** looks something like a housefly except that it has a strong piercing beak and sucks blood from animals. It is also supposed to be the insect which carries the germs of infantile paralysis.

The smaller horn fly **(Haematobia serrata)** swarms about the bases of the horns of cattle, biting constantly.

LIFE HISTORY

Flies (Fig. 241) breed about filth and decaying matter though they can and do breed in any wet fermenting vegetable or animal matter. The maggots are hard to kill; they will live in pure kerosene for over an hour and even more than thirty minutes in alcohol. They have even been bred from the open boxes of snuff on a druggist's counter, though tobacco is supposed to be quite injurious to insects.

After the housefly's eggs are laid, it takes about **eight hours for them to hatch into maggots.** These finish their growth in **six to seven days,** burrowing into the ground "under the manure pile" (hence the need of concrete floors) and transform into brown **puparia,** from which they emerge as **adult flies in three days.**

Hodge and Dawson have summed up the rapid increase in flies most tellingly in the following words: "After coming out as adults, they fly about over an area **not generally more than one thousand yards in diameter,** and feed and drink from two hundred to three hundred times a day **for from ten to fourteen days** before maturing their first batch of eggs. This actually delivers the enemy into our hands. It means that, with flytraps on every garbage can and swill barrel, and with everything most attractive to flies very carefully kept in these receptacles, not a single fly will succeed in feeding for two weeks without getting caught. In this case no more eggs will be laid, and the pests will vanish.

"Allowing ten days of feeding between emergence and oviposition, figuring that a fly lays 150 eggs at a batch and lives to lay six batches, compute the increase of a pair of flies beginning to lay May 1. Half the progeny are supposed to be females. Test the following figures:

May 10	152 flies.
May 20	302 flies.
May 30	11,702 flies.
June 10	34,302 flies.
June 20	911,952 flies.
June 30	6,484,700 flies.
July 10	72,280,800 flies.
July 20	325,633,300 flies.
July 30	5,746,670,500 flies.

"As this last amount makes 143,675 bushels of flies resulting from **a single pair of flies in three months**, one can estimate what the result will be if allowed to breed unrestrained during August and September beside.

"The common sense question, then, is, why not let this pair of flies catch themselves in May? This rapid increase also means that anything short of extermination is hardly worth the effort. A fly is possessed of no more cunning than shot rolling down a board, and the last pair will run into a trap as easily as the first. Why not let them all catch themselves?"

During the winter, especially in cold climes, most of the flies are killed, but probably some maggots pass the winter underground and in stables where it is sufficiently warm, coming forth in the spring when the weather warms up.

It has often been assumed that burying debris of various kinds would kill the maggots. This is not true as the maggots have crawled up through six feet of earth with which they were covered.

The best method of handling debris, such as manure, is to spread it on the land daily. This is especially valuable, as manure loses almost half its fertilizing power if stored. The sun will dry it and this will also prevent the moisture which maggots need in order to thrive. However, if this cannot be done, then a solution of iron sulphate (copperas), two pounds to the gallon of water, may be thrown over such matter. Chloride of lime is expensive and the fumes (chlorine) are likely to injure the farm animals.

FLY KILLERS

The Kansas Board of Health Bulletin gives the following methods of killing flies:

"A cheap and perfectly reliable fly poison, one which is not dangerous to human life, is bichromate of potash in solution. Dissolve one dram, which can be bought at any drug store, in two ounces of water, and add a little sugar. Put some of this solution in shallow dishes and distribute them about the house."

"One of the best fly killers that can be used in the home is a teaspoonful of formalin in a quarter of a pint of water. When this is exposed in a room it will be sufficient to kill all flies. They seem to be fond of the water. Care should be taken to place it beyond the reach of children."

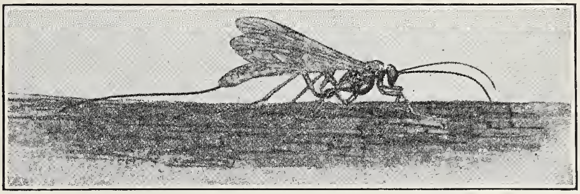
"To quickly clean a room where there are many flies, burn pyrethrum powder. This stupefies the flies, when they may be swept up and burned."

And the Agricultural Extension Department of the International Harvester Company suggests the following ointments and sprays to keep flies away from cattle:

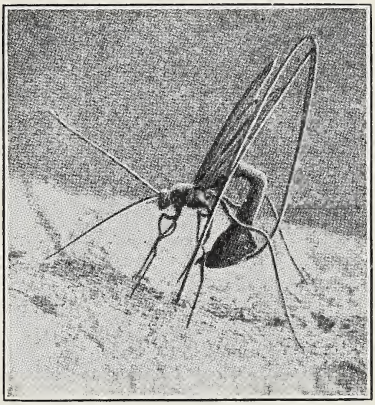
(Any of the following must be applied frequently, as few will keep flies away for more than a day or two following their application.)

One pound rancid lard, one-half pint kerosene.

Mix until a creamy mass forms. Best applied with cloth or with bare hand. Rub thinly over the backs of the cows.



I.



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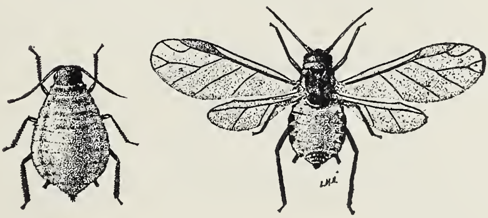

III.

Fig. 242.

I. Ichneumon-fly. Natural size.

II. Thalessa boring in an ash tree to deposit its eggs in the burrow of a horntail larva, a wood borer. From photograph, natural size. (After Davison.)

III. Corn root aphis *(Aphis maidiradicis)*, winged and wingless female. The two black processes at the rear are *Cornicles.* (From Needham's "General Biology" by permission The Comstock Pub. Co.)

Three parts fish oil, one parτ kerosene. Apply with small spray pump.

Two parts crude cottonseed oil or fish oil, one pint pine tar. Apply with large paint brush.

PARASITIC INSECTS

Many kinds of insects live parasitically for part of their lives, and many live as parasites for their whole life. The true sucking lice and the bird lice live as external parasites on the bodies of their host throughout their entire lives, but they are not fixed—that is, they retain their legs and power of locomotion, although they have lost their wings through degeneration. The lice deposit their eggs on the hair of the mammal or bird that serves as host. The young hatch and immediately begin life as parasites, either sucking the blood or feeding on the hair and feathers of the host. There are several families of the order **Hymenoptera,** all of whose members live as parasites during their larval stage. These hymenopterous parasites are called **ichneumon** ( ) flies. (Fig. 242.) The ichneumon flies are parasites on other insects, especially of the larvae of beetles, moths, and butterflies. According to Ealand, "the ichneumon flies do more to keep in check the increase of injurious and destructive caterpillars than do all our artificial remedies for these pests. The adult ichneumon fly is four-winged and lives an active, independent life. It lays its eggs either in or on or near some caterpillar or beetle grub, and the young ichneumon, when hatched, burrows into the body of its host, feeding on its tissues, but not attacking such organs as the heart and nervous ganglia, whose injury might mean immediate death to the host. The caterpillar lives with the ichneumon grub within it, usually until nearly time for its pupation. In many instances, indeed, it pupates with the parasite still feeding within its body, but it never comes to maturity. The larval ichneumon fly pupates either within the body of its host or in a tiny silken cocoon outside of its body. From the cocoons the adult winged ichneumon flies emerge, and after mating find another host on whose body to lay their eggs."

As an example of a parasite living upon another parasite, though one of these uses a tree as its host, the remarkable ichneumon fly **Thalessa** (Fig. 242) is an excellent example. This animal, which has a very long, slender, flexible ovipositor, finds a spot in a tree where the insect **Tremex columba** ( ), commonly called the **pigeon horntail,** has deposited its eggs about a half inch below the surface of a growing tree. When these eggs are converted into larva, the larva digs still deeper into the tree, filling up the open space behind it with tiny chips. Through a very extraordinary instinct the **Thalessa** finds the spot opposite where the **Tremex** larva lies and "elevating her long ovipositor in a loop over her back, with its tip on the bark of the tree, she makes a derrick out of her body and proceeds with great skill and precision to drill a hole into the tree. When the **Tremex** burrow is reached, she deposits an egg in it. The larva that hatches from this egg creeps along this burrow until it reaches its victim, and then fastens itself to the horntail larva which it destroys by sucking its blood. The larva of **Thalessa,** when full grown, changes to a pupa within the burrow of its host, and the adult gnaws a hole out through the bark if it does not find the hole already made by the tremex."

Practically all the **mites** ( ) and **ticks** ( ), animals closely allied to the spiders, live parasitically.

Truly Dean Swift was right when he said:

"Great fleas have little fleas
Upon their backs to bite 'em,
And little fleas have lesser fleas,
And so **ad infinitum.**"

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CHAPTER XXV

HISTORY OF BIOLOGY

IT is generally conceded that those who have been with a business organization throughout its growth period know most about that business. Such men not only understand a thousand details of the work that others do not, but they have definite reasons for their actions and policies. The same truth holds good in science. But as none of us were present when science began, the only way we can obtain such an understanding is to read the story of those who were present; as a consequence, the history of any branch of science becomes an important study in the college curriculum.

In reading history we are always inclined to pass some kind of judgment on the characters there found. This judgment is, however, quite likely to prove erroneous, unless we first know something of the times in which they lived, the obstacles they had to overcome, and the reasons they had for beginning work in new fields.

We must weigh the evidence on all sides of a question very carefully, so as not to confuse **conspicuousness with importance.** For example, an inventor is likely to be widely known because men at large can see, use, and understand his invention; but, as soon as another inventor improves, or brings about another apparatus which takes the place of the first invention, the first inventor ceases to interest men, and is soon forgotten.

Such a lack of consideration does not apply to the **real scientist—the discoverer of a new principle**—for, every invention and every application which his principle brings about in future time, proves that principle to be just so much the more important, and causes the scientist to be held in greater and greater esteem through onflowing years.

It is, therefore, the real scientists, the true originators and discoverers of principles, who must be known and honored.

First, then, let us try to catch a glimpse of the times in which men of past ages worked.

From the very earliest period of which we possess records, men have been interested in agriculture and medicine—which means, **botany** and **zoölogy.** Botany, in so far as a practical knowledge of food-plants was essential to successful agriculture, and in so far as a practical knowledge of medicinal plants was essential for the health of man and his animal servants. Zoölogy, in so far as a practical knowledge of the breeding of cattle and sheep was essential to a successful livelihood, and in so far as a knowledge of the human body was essential to prevent wounded men from bleeding to death.

Aristotle (384-322 B. C.), who was the pupil of **Plato**, was one of the first men to think of botany and zoölogy as definite branches of study. His great contribution to Biology was the discovery of the fact that **nature worked by definite fixed laws**—what we now call the **law of continuity.**

This discovery is intensely important because it made experimental science possible. There would be but little use in spending months and years in attempting to prove anything, if the laws of nature worked differently at different times, under the same conditions; for, the real value of experimenting is found in one's ability **to prophesy** that the same result will always take place if the same experiment is performed under the same conditions.

The first mark of a true scientist is accurate observation and perfect description, and the second is the power of visualization, by which he can build up and mold his interpretations into a **principle.**

Aristotle had a mind of the highest type, and so his generalizations still hold good after a lapse of thousands of years, provided, always, that his facts were correct. He did not have the instruments for accurate observation that we now have, so he often had to take for granted many things which have since been proved erroneous. But, his logic never failed him when his facts were right.

Theophrastus (370-286 B. C.) laid the foundations of botany. The astounding point that meets one in the reading of these old philosophers is that they were able to work out so great an amount of detail with the poor equipment they had, when we, with all our modern improved apparatus, must search most diligently before we can accomplish the same results.

As medical men were the first workers in Biology proper, **Hippocrates** (460-370 B. C.) the father of medicine, must be mentioned. He made medicine a separate science and set forth the ideals of the medical man which are still an inspiration to all.

Dioscorides (about 64 A. D.), an army surgeon under Nero, and **Galen** (131-201 A. D.), physician to Marcus Aurelius and his son Commodus, were both Greek physicians. The former originated the pharmacopoeia, which was the standard textbook of botany for some fifteen centuries. The latter wrote an anatomy and physiology which also was a standard textbook for medical students for the same length of time.

Pliny the Elder (23-79 A. D.) wrote a book which, although supposed to be accurate, had fact and fancy blended to so considerable an extent that it is hard to separate them.

The men mentioned above are the only biological workers of whom we have any record up to the time Christianity began to function.

The Roman Empire was mistress of the world at this time, and

pleasure was the Roman ideal. Christianity strenuously opposed such an ideal, and soon won Emperor and people to its side. The moment this occurred, all efforts on the part of both student and soldier were directed toward performing such acts as would bring glory to the God they had accepted. And, as always, when the ideal of a nation is thrown aside, the pendulum swings completely over to the other side. Consequently, after Christianity was adopted, **suffering**, from having been considered a burden and a nuisance to men who held pleasure as their ideal, became something to be endured and practically enjoyed, inasmuch as he who suffered was thus imitating in some small measure the sufferings of the founder of Christianity. It follows that no great impetus was given to work that had for its object the relief of physical discomforts. At this time, also, barbarian hordes were a constant menace, and wars and rumors of wars not only kept men in the field, but forced all energy to be directed toward setting up some kind of military and defensive stability. And, while many scientific applications are produced for destructive purposes in war, there can be no true science at such time. Little serious studious work can be accomplished unless there is leisure and freedom from danger.

At this time there were only two fields of work in which a youth of ambition might enter—the army and the Church. The first attracted men who sought physical power, while the second attracted those who sought knowledge.

The Church, therefore, established universities and libraries in the monasteries—the only place where one could find men interested in learning. It was here that the works of the great writers of antiquity were preserved and used during the times when wars were not being waged.

Even during these trying times some of the monks compiled animal stories which were, however, concerned principally with pointing out a moral. Such stories were collected in book form and became known as the **Physiologus.** The physiologus in turn developed into another book of similar import called the **Bestiaries,** while on the botanical side a book, which may be compared with the bestiaries, was the **Hortus Sanitatis.**

Later, another botanical work appeared, called the **Herbals.**

In the thirteenth century, Europe became somewhat settled. There was then sufficient leisure and safety to permit men to lead studious lives. The fame of the great scholars of that day spread rapidly. Everywhere studious men sought whatever books they could find, and read them. Printing had not yet been invented, so it was only in the monastery libraries that books (written by hand) could be found. These were read with avidity, and much which had lain neglected during centuries of war and turmoil now was made known to the new generation. This period from about 1250 to 1500 is, therefore, called the **Renaissance** or **period of re-birth.**

During the thirteenth century, the Dominican Monk, **Albertus Magnus** (1193-1280), began working on physical experiments, while the Dominican, **Thomas Aquinas** (1225-1274), began to collect and coördinate all the scientific and philosophical knowledge of his day.

Following these came the Franciscan Monk, **Roger Bacon** (1214-1294), the real father of modern science. Among his many writings we find the first clear and unmistakable statements from which our knowledge of modern lenses date. His work is like a modern monograph in that it gives recognition to the opinions of others.

The old Romans had, it is true, used pieces of glass with water in between for magnifying purposes, but it was Bacon who set men on the right path regarding true observation, description, and the use of modern laboratory instruments.

Gesner (1516-1565) wrote his **Historia Animalium** in several volumes between 1551 and 1587, which was widely read, although he had but little influence on successive generations.

The next truly great name in the history of Biology is that of **Vesalius** (1514-1564). He wrote the **De Humani Corporis Fabrica** in 1543. Up to this time the surgeon would not soil his hands by touching and cutting the body. Such work was left for barbers, who performed their dissections and operations under the direction of the surgeon. Vesalius dissected with his own hands, and then described and pictured what he found. Vesalius' old master, **Jacobus Sylvius,** was a strenuous opponent of his pupil, as was also Vesalius' own pupil, **Columbus.** However, another pupil of Vesalius, who later became his successor at the University of Padua, was **Fallopius** (1523-1562), who built upon the work of his master.

Harvey (1578-1657) in 1628 published his **Excercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus**, in which he showed conclusively that the blood flows in a circle from the heart through the blood-vessels and back again to the heart.

In about 1600, compound microscopes were invented, and it is from this time forward that the great microscopical discoveries were made, which have changed our modern conception of many ancient problems.

Robert Hooke (1635-1703) wrote his **Micrographia** in 1665, in which he called attention to the "little boxes or cells" of which plants are composed. It is he, therefore, who gave us our first notion of the cell.

The next important name is that of **Van Leeuwenhoek** (1632-1723) who first saw bacteria, infusoria, yeast, rotifers, hydra, and a host of other organisms which were totally unknown up to his time. His work, which attracted most attention in the scientific world, however, was his description of **spermatozoa.** His imagination carried him away, for he was sure he saw definitely-formed tiny human beings in the spermatozoa. A great conflict was waged by those who agreed with him and his school, who were known as spermists, insisting that it was the sperm that was the all important factor in producing life, and the opposing school known as ovists which insisted that it was the egg and not the spermatozoa which developed into new offspring.

Swammerdam (1637-1680), in his **Biblia Naturae,** compiled long and painstaking accounts of his researches on the anatomy of insects. Up to his time, insects were considered only unorganized physical masses.

Malpighi (1628-1694) of Bologna worked on plants and animals. He made elaborate studies and illustrated them, on the development of the plant-embryo, as well as on the embryology of the chick, the anatomy of the silk-worm, and the structure of glands.

Chronologically, the **systematists** should be mentioned at this point, but logically, it is better to introduce the student to the whole subject of classification and the men who did the classifying at the same time. Therefore, this subject will be treated in the next chapter.

As soon as there is any considerable classification and description of a subject, men begin to divide that subject into individual parts or units so that workers may narrow their field and confine their work to such a limited group or unit.

Comparative anatomy, physiology, histology, embryology, genetics, and **organic evolution,** are the main divisions into which Biology is thus divided.

The work done by first-year students of Biology, as set forth in this book, consists of studying a **type-form** of the principal phyla of plants and animals, and then attempting to develop biological principles from the knowledge thus gained. This first-year work, therefore, includes the fundamentals of botany and zoölogy. The third semester's work is confined to the specialized study of **embryology,** and the fourth semester's work is **comparative anatomy and physiology.** In this last semester's work the student studies in detail **each organ or organ-system** of the great divisions of zoölogy and then compares these, system by system.

Probably the first man to attempt this latter method was **Severinus** (1580-1656) of Naples. In 1645 he published a volume suggesting that all vertebrates and man had much in common, structurally. However, over a century before this time, **Belon** had made drawings of the skeletons of birds and man and placed them side by side so that differences and similarities could be noted. Then came **Tyson** (1650-1708) of Cambridge, who is the father of our modern method of treating comparative findings in monograph form. His work was a comparison of man and monkeys.

Cuvier (1769-1832) of Paris is, however, the first of the great men in this field of work. He was the first to embrace both living and extinct forms in his comparisons, and he also obtained a wider grasp of the problem confronting him than any of his predecessors. A good illustration of the synthesis sought for, and the breadth of knowledge desired in this department of research, can be found in his famous statement, "Give me a tooth, and I will construct the whole animal."

This is the keynote to **comparative study**. It means that every change in function modifies a structure, and that, if we can know thoroughly all there can be known about function and its effect on structure, and every change in one structure which may change a related structure, we can tell what the functions must have been, in a given structure, and vice versa.

There are men who were lesser lights in the field of comparative anatomy even before Cuvier's time, whose names it is well to know: **John Hunter** (1728-1793), who founded the Hunterian Collection in England; **Camper** (1722-1789) of Groningen, and **Vicq d'Azyr** (1748-1794) in Paris. All of these did synthetic work, but their breadth of knowledge, view, and vision fell far short of that of Cuvier.

Following Cuvier came **Milne-Edwards** and **Lacaze-Duthiers** in France; **Meckel, Rathke, Johannes Müller,** and **Gegenbaur** in Germany; **Owen** and **Huxley** in England; **Aggassiz, Cope,** and **Marsh** in America.

When men once became interested in the great structural problems of zoölogy it was but natural that others should become interested in those that were functional. Here was the birth of modern **physiology.** The medical men were the first to do work in these fields. They established systems of thought known as the **iatro-mechanical** and **iatro-chemical schools.**

Haller (1708-1777) took the work of these men, surveyed it, and evaluated it, so that he may really be called the **father of modern physiology.**

The first work in physiology was done on nutrition and respiration. **Reaumur** (1683-1757) of Paris, and the Abbe **Spallanzani** (1729-1799) of Pavia did the most remarkable work in this field, although they had forerunners on whose work they built in turn.

Such forerunners were **van Helmont** (1577-1644), **Sylvius** (1614-1672), **Bishop Stensen** (1638-1686), **de Graff** (1641-1673), **Peyer** (1653-1712), and **Brunner** (1653-1727).

The great names in chemistry whose work affected biological students are primarily **Boyle** (1627-1691), **Priestly** (1732-1804), and **Lavoisier** (1743-1794).

In physiology proper the greatest names in Germany are: **Liebig** (1803-1873), **Wöhler** (1800-1882), the brothers **Weber** (E. H., 1795-1878, and W. E., 1804-1891), **Ludwig** (1816-1895), **Helmholtz** (1821-1894), **Johannes Müller** (1801-1858), and **du Bois-Reymond** (1818-1896). In France, **Dumas** (1800-1884), **Magendie** (1783-1889), and in England,

Hall (1790-1857). The greatest of the physiologists is undoubtedly **Johannes Müller.**

In botanical physiology, **Hale** (1677-1761), is the greatest, while **Cesalpino** (1519-1603), **Jung** (1587-1657), and **van Helmont** (1577-1644), occupy high places.

Ingen-Housz (1730-1799) was the first to show that carbon dioxide from the air is broken down in the leaf when the plant receives sunlight, and that the carbon is retained and assists materially in nutrition and growth.

De Saussure (1740-1799) showed further that water and various salts from the soil produced the remaining factors in this process, while **Boussingault** (1802-1887) gave us our knowledge of chlorophyl.

Haller and **van Leeuwenhoek** were **"pre-formationists."** They supposed that each sperm or egg-cell already contained an embryo somewhat fully formed, and that all that occurred during the growth period was an enlarging of the parts which were already present. Such an idea meant that every human germ-cell must have every other complete human being that could ever descend from it, within itself, fully formed, but very small. We know now that both those who held this theory and those who opposed it were wrong. There must, of course, be present in each germ-cell a **potentiality** which can develop into what it is to become, but this by no means signifies that the embryo possesses a definitely formed embryo within it in turn. The new embryo is always organized little by little until it becomes the completed individual adult organism.

However, it is natural to see how and why observers thought they saw the complete embryo in the egg. In our study of embryology we shall see that when the hen lays an egg, it is already from twenty-two to thirty-six hours old, and consequently, even when we have a freshly laid egg (provided it is fertile), there is already an embryo which can be seen. It was with material of this kind that these men had to work.

Wolff (1733-1794) had proved that the pre-formationists were in error, but **Haller**, who held the intellectual reins of workers in zoölogy at the time, refused to accept it, and so the lesser lights also refused.

It was but natural that, after **Hooke** had observed that plants were composed of cells, something should be done with such a finding. **Brown** (1773-1858), working on the cell, discovered the **cell nucleus in** 1831, and the botanist **Schleiden** (1804-1881), and the zoölogist **Schwann** (1810-1882) published their works in 1838 and 1839, respectively, showing that plants are developed from cells, and that plants and animals are alike in being composed of cells.

An important point was made in suggesting that each cell has two functions: one to perform the work itself and the other to perform a task which makes it an integral part of a larger organism.

Schultze (1825-1874) in the early sixties established the idea of **protoplasm** as the living substance of all cells. This protoplasm was called by Huxley the **"physical basis of life."**

In embryology **Fabricius** (1537-1619) published a paper describing the sequences of development in the hen's egg up to the time of hatching. **Harvey** was a pupil of Fabricius, and built upon the work of his master. These men opposed the pre-formationists, and called their theory **epigenesis**—which simply means that the embryo arises by a gradual differentiation of unformed material in the egg.

Malpighi in 1672 sent two important papers on embryology to the Royal Society, but apparently the time was not yet ripe for his work and it was neglected for nearly a century. He stood with the epigenetic group.

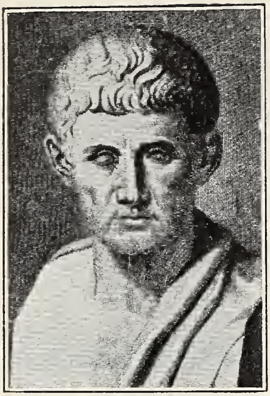
Bonnet (1720-1793) was one of the important men at this time who threw the weight of his influence with Haller toward the pre-formationists.

At present embryologists hold, as was stated above, that there really is an organization of some kind in both egg and sperm, but that no embryonic shape has yet been established. The definite shape comes forth only by the gradual differentiation of the unformed (but not unorganized) matter. We may, therefore, say that "the whole future organism is potentially and materially implicit in the fertilized egg cell," which means that both sides were partially right.

However, the greatest name in embryology is **von Baer** (1792-1876). His work was done in the thirties of the last century. He is the father of **comparative embryology.** It was he who first noted and described **cleavage, germ-layers, tissue, and organ differentiation,** and gave us the well-known **"recapitulation theory,"** now often called **Haeckel's "Law of Biogenesis,"** on account of Haeckel's popularization of it. It will be remembered that this theory holds that embryos pass through the adult stages of the race to which they belong.

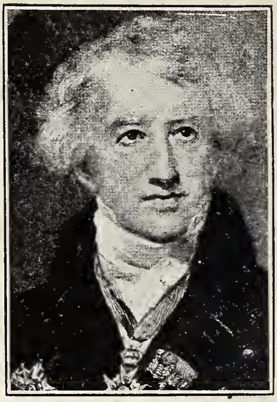
The origin of life has always been an interesting speculative subject for thinking men, and many and mysterious are the ways in which life was supposed to spring forth spontaneously. Aristotle thought that mice developed from the river's mud, while later writers suggested that old rags and cheese combined in a dark cellar would produce the same result. The history of this subject makes more than fascinating reading.

Francesco Redi (1626-1698) was probably the first man to demonstrate experimentally that life did not spring forth spontaneously as commonly supposed. He placed very thin cloth over a dish containing decaying meat and found that, when flies were thus prevented from coming in contact with the meat, no maggots formed, although maggots were always supposed to arise spontaneously from decaying meat. But Redi himself found parasites of various kinds within the bodies of other



Aristotle, 384-322 B. C.

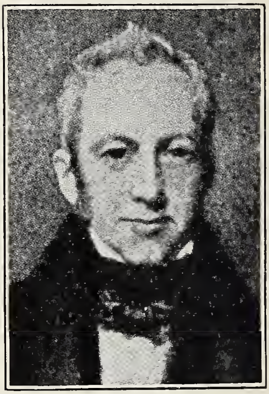
Francesco Redi, 1626-1697.



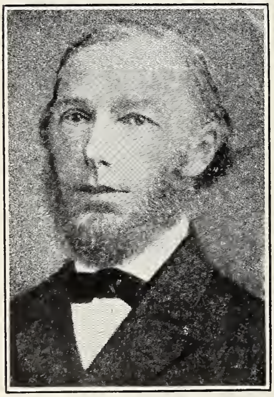
Cuvier, 1769-1832.

Lazzaro Spallanzani, 1729-1799.

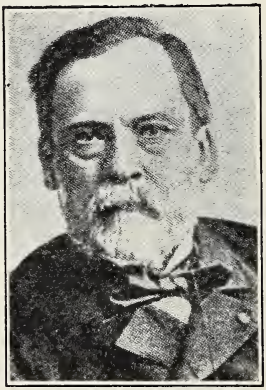
Johannes Müller, 1801-1858.



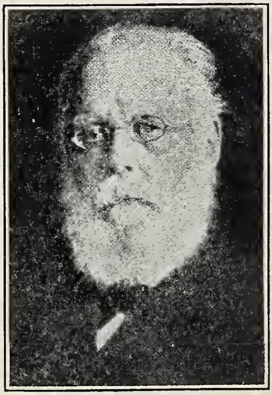
Robt. Brown, 1773-1858.



Max Schultze, 1825-1874.



Louis Pasteur, 1822-1895.



August Weismann, 1834-1914.

Fig. 243.

(Aristotle and Max Schultze, from Needham's "General Biology" by permission of The Comstock Publishing Co., Publishers. Pasteur, from G. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Sons & Co., Publishers. Remaining photographs from Wm. A. Locy's "Biology and Its Makers" by permission of Henry Holt & Co., Publishers.)

animals, and these he could not account for; so his experiment, while a classic, did not settle the problem for others any more than it did for himself. The settling of this vexed question was left for **Louis Pasteur** (1822-1895), who first showed that decay was not the cause of micro-organisms but the result of them. His experiments were made while working on fermentation problems, and it is from his work that all modern medicine dates, for he was the founder of the science of bacteriology.

In **genetics** or **inheritance**, from a purely biological angle, **August Weismann's** (1834-1914) work, **The Germ Plasm**, stands out prominently. It was Weismann who called attention to the fact that the bodily characteristics of any individual have but little, if any, effect on succeeding generations. He held that **germ-plasm** alone carries inheritance. In other words, that acquired characteristics are not likely to be inherited, and that, if we are to make any change in future generations, we must first learn how to make a change in the germ-cells.

Francis Galton (1822-1911) gathered a great quantity of statistics on the stature of parents and children and published the result of his research in the eighties.

The most important name in the study of inheritance is that of the Augustinian monk, **Johann Gregor Mendel** (1822-1884), who combined experimental breeding of plants with a thoroughly scientific philosophy, and evolved from this combination the **Mendelian laws** which are now used wherever breeding experiments are performed, whether on plants or animals.

In the field of **organic evolution,** one may find among the ancients many thoughts which show conclusively that they were not unaware of a gradual change from smaller beginnings to greater and more developed products. Thus **St. Augustine** (died 604) calls attention to the fact that a God is the greater, the more potentialities he can enclose within a smaller area, which potentialities can then unfold and evolve.

Among the moderns, **Buffon** (1707-1778), was the first to obtain a clear inkling of geographical isolation, struggle for existence, and artificial and natural selection, and he propounded a theory of how variations came about through environment.

Erasmus Darwin (1731-1802) wrote on changes going on in the animal world and embodied his ideas in verse.

Lamarck (1744-1829) is the most philosophical, which means the most profound, of all the writers of the evolutionary school, as he actually tried to explain WHY changes took place in the organic world.

Cuvier (1769-1832), who was a contemporary of Lamarck, and who at that time held the highest attainable place in the zoölogical world, was a consistent opponent of Lamarck, but **Geoffroy Saint-Hilaire** (1772-1844), though never attaining the rank of Lamarck, was a staunch upholder of the Lamarckian principles, and **Goethe** (1749-1832), the famous poet, who was also a famous scientist of his day, became a disciple of the new doctrine.

Lyell (1797-1875), the Englishman, in the early thirties of the last century wrote his **Principles of Geology** which convinced men that the same causes now in action always had been, and that we could, therefore, by studying the time it took to make present changes in the earth's surface, estimate the length of time and the age of the various strata of the earth.

With the intellectual soil prepared in this way, **Charles Darwin** (1809-1882), published his epoch-making book, **The Origin of Species by Natural Selection,** in 1859. Darwin accepted, without explaining, the fact that variations do occur. He assumed that the origin of existing species could be explained by accepting the fact that variations did occur, and that nature then selected the organisms which should continue to exist by killing off those which did not inherit as many variations of a survival value. He assumed that acquired characteristics were inheritable, and that the struggle for existence eliminated the unfit. Darwin had spent twenty years in gathering the facts on which he based his theory, but **Alfred Russel Wallace** (1822-1913) had reasoned out a similar theory without having the facts that Darwin had, and it is an interesting coincidence that both men were working independently on the same thought at the same time. Darwin was willing to surrender all his work to the younger man, but Wallace insisted that Darwin was to have the credit as the latter had done such an immense amount of work on the matter.

Evolution now serves the biological world as a sort of general plan of the results of heredity, while **genetics deals with the factors which produce these results.**

Thomas Huxley (1825-1895), though not a believer in the Darwinian theory of natural selection, sprang to the defense of Darwin, primarily, as Professor Poulton says, because Darwin was so constantly and persistently treated unjustly. It was Huxley who made Darwinism popular. **Hooker** (1817-1911) in England, **Haeckel** (1834-1919) and **Weismann** in Germany, and the botanist **Gray** (1810-1888) in America, were early converts. Haeckel, however, was too much of the showman, and was always willing to sacrifice truth and accuracy to win his point.

Summing up what has been said, we may say that **the basis of greatness in science is not the brilliancy of an individual discovery, but the finding and enunciating of a principle which can find many applications by those who follow.**

The great findings, considered from this point of view of obtaining principles which have a wide influence in Biology, may be said to be the **discovery of protoplasm; the establishment of the cell-theory; the** theory of organic evolution; the demonstration that germs are a tremendous factor in disease; and the experimental study of inheritance as suggested by the work of Mendel and Weismann.

And the most important writings of the most important men may be summarized here by following Professor William Locy's account, which we have modified slightly.

THE MOST NOTABLE MEN AND WRITINGS IN BIOLOGY

The progress of Biology has been owing to the efforts of men of very human qualities, yet each with some special distinguishing feature of eminence. Certain of their publications are the mile-stones of the way. It may be worth while, therefore, in a brief recapitulation to name the books of widest general influence in the progress of Biology. Only those publications will be mentioned that have formed the starting point of some new movement, or have laid the foundation of some new theory.

Beginning with the revival of learning, the books of **Vesalius, "De Corpora Humani Fabrica"** (1543), and **Harvey, "De motu Cordis et Sanguinis"** (1628), laid the foundations of scientific method in Biology.

The pioneer researches of **Malpighi** on the minute anatomy of plants and animals, and on the development of the chick, best represent the progress of investigation between Harvey and Linnaeus. The three contributions referred to are those on the "Anatomy of Plants" **(Anatome Plantarum)**, (1675-1679); on the "Anatomy of the Silkworm" **(De Bombyce,** 1669); and on the "Development of the Chick" **(De Formatione Pulli in Ovo** and **De Ovo Incubato,** both in 1672).

We then pass to the **"Systema Naturae"** (twelve editions, 1735-1768), of Linnaeus, a work which had wide influence in stimulating activity in the systematic study of botany and zoölogy.

Wolff's "Theoria Generationis," 1759, and his **"De Formatione Intestinorum,"** 1764, especially the latter, were pieces of observation marking the highest level of investigation of development prior to that of Pander and von Baer.

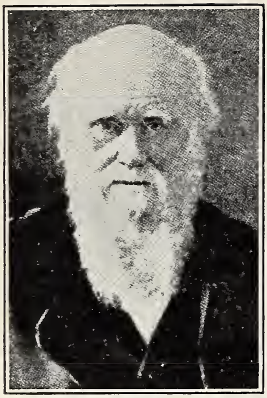
Cuvier, in **"Le Regne Animal,"** 1816, applied the principles of comparative anatomy to the entire animal kingdom.

The publication in 1800 of **Bichat's "Traite des Membranes"** created a new department of anatomy called histology.

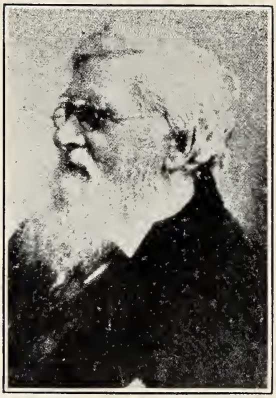
Lamarck's book, **"La Philosophie Zoölogique,"** 1809, must have a place among the great works of Biology. Its influence was delayed for more than fifty years after its publication.

The monumental work of **von Baer** "On Development" **(Ueber Entwicklungsgeschichte der Thiere)**, 1828, is an almost ideal combination of observation and conclusion in embryology.

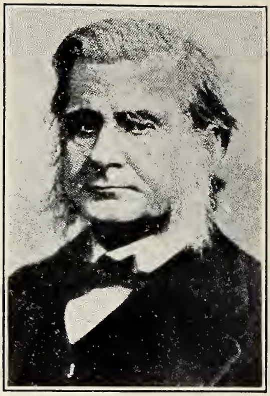
The **"Mikroscopische Untersuchungen,"** 1839, of **Schwann** marks the foundation of the cell-theory.



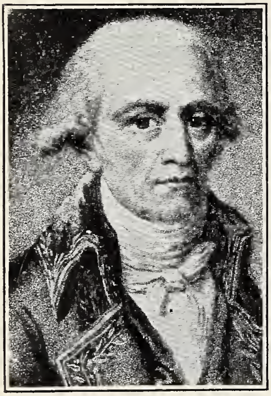
Charles Darwin, 1809-1882.



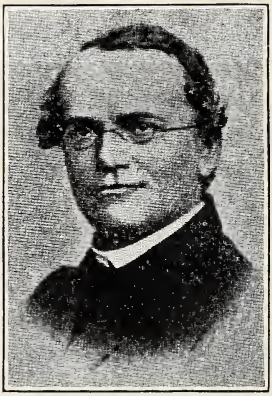
Alfred Russell Wallace, 1823-1913.



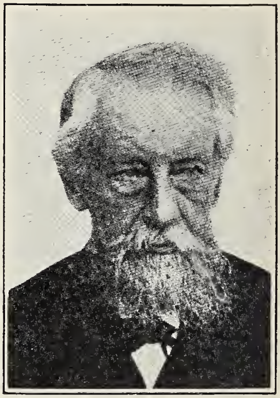
Thomas Henry Huxley, 1825-1895.



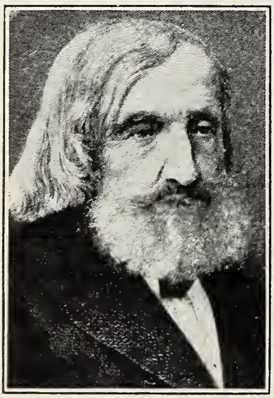
Lamarck, 1744-1829.



Johann Gregor Mendel, 1822-1884.



Hugo De Vries, 1848—



Karl Ernst von Baer, 1792-1876.

M. Schleiden, 1804-1881.

Theodor Schwann, 1810-1882.

Fig. 244.

(De Vries and Mendel, from G. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Son & Co., Publishers. Remaining photographs from Wm. A. Locy's "Biology and Its Makers" by permission of Henry Holt & Co., Publishers.)

The "Handbook" of **Johannes Müller (Handbuch der Physiologie des Menschen),** 1846, remains unsurpassed as to its plan and its execution.

Max Schultze in his treatise, **"Ueber Muskelkoerperchen und das was man eine Zelle zu nennen habe,"** 1861, established one of the most important conceptions with which Biology has been enriched, viz: the protoplasm doctrine.

Darwin's "Origin of Species," 1859, is, from our present outlook, the great classic in Biology.

Pasteur's "Studies on Fermentation," 1876, is typical of the quality of his work, though his later investigations on inoculations for the prevention of hydrophobia and other maladies are of greater importance to mankind.

Mendel's "Versuche über Pflanzen-Hybriden" appeared in 1865 in a little periodical published in Brünn, Austria, where Mendel was abbot of an Augustinian monastery. It remained entirely unknown to the scientific world until 1900 when three workers in the natural sciences rediscovered it. These men were De Vries, Torrens, and Tschermak.

Mendel's work has become the foundation upon which all modern research along genetic lines is based. Castle says, "Mendel had an analytical mind of the first order which enabled him to plan and carry through successfully the most original and instructive series of studies in heredity ever executed," and Bateson suggests that "had Mendel's work come into the hands of Darwin, it is not too much to say that the history of development of evolutionary philosophy would have been very different from that which we have witnessed."

Weismann's "The Germ-Plasm, a Theory of Heredity," appeared in 1893. It demonstrated the "continuity of the germ-plasm," a valuable starting point for theorizing upon Mendel's laws.

De Vries' "Die Mutationstheorie," published in 1901, caused much of Darwin's theory, that evolution comes about gradually, to be set aside. The sudden springing forth of new forms, rather than a slow change requiring thousands of years, won many scientific men to it. In fact, all modern evolutionary theories follow either the Darwinian or the De Vriesian type, or build new ones on modifications of these.

It is somewhat puzzling to select a man to represent the study of fossil life. One is tempted to name **E. D. Cope** (1840-1897), whose researches were conceived on the highest plane. **Zittel** (1839-1904), however, covered the entire field of fossil life, and his **"Handbook of Paleontology"** (1876-1893) is designated as a mile-post in the development of that science.

Before the Christian era, the works of **Aristotle** and **Galen** should be included.

From the viewpoint suggested, the most notable figures in the development of Biology are: **Aristotle, Galen, Vesalius, Harvey, Malpighi,**

Linnaeus, Wolff, Cuvier, Bichat, Lamarck, von Baer, J. Müller, Schwann, Schultze, Darwin, Pasteur, Zittel, and **Mendel.**

Such a list is, as a matter of course, arbitrary, and can serve no useful purpose except that of bringing together into a single group the names of the most illustrious founders of biological science. The individuals mentioned are not all of the same relative rank, and the list should be extended rather than contracted. Schwann, when the entire output of the two is considered, would rank lower as a scientific man than Koelliker, who is not mentioned, but the former must stand in the list on account of his connection with the cell-theory. Virchow, the presumptive founder of pathology, is omitted, as are also investigators like Koch, whose line of activity has been chiefly medical.

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CHRONOLOGICAL TABLE OF IMPORTANT BIOLOGICAL EVENTS

B. C.

540 Xenophanes was first to recognize fossils as proving that the earth was formed under the sea and rose out of it.

500 Heraclitus, often called the first evolutionist. He first advanced the principle that "all things flow."

450 Empedocles was first to suggest natural selection and survival of the fittest.

400 Hippocrates is called "the Father of Medicine."

350 **Aristotle,** founder of zoölogy.

320 Theophrastus, first botanist.

320 Erasistratus, first to give mechanical explanation of disease symptoms.

300 Herophilus, first anatomist.

A. D.

79 Pliny wrote the first popular natural history.

160 **Galen** founded medical physiology.

1266 Bacon wrote his Opus Majus.

1542 **Vesalius,** founder of modern anatomy.
1548 Falloppio, anatomist.
1551 Gesner gathered the first botanical garden (of fruits and flowers) and arranged the first zoölogical museum.
1560 Eustachio, anatomist.
1583 Caesalpinus classified plants by flowers.
1590 Janssen, J. and Z., discovered the compound microscope.
1603 Fabricius discovered valves in the veins.
1603 **Harvey** discovered circulation of the blood.
1622 Ascello discovered the lacteals.
1649 Rudbeck discovered the lymphatics.
1650 Swammerdam was first great student of insects in relation to plants and medicine.
1661 **Malpighi,** founder of pathology. He discovered the capillaries in the lungs; founded modern embryology by a study of the incubation of the chick (1672).
1667 Leeuwenhoek, first to see bacteria.
1668 **Redi** disproved spontaneous generation of insects by the discovery of eggs and larvae. He wrote "Esperienze intorno alla Generazione degl' Insetti."
1670 Mayow studied animal respiration.
1671 Hooke worked out microscopical structure of plants.
1680 Borelli proved that all the movements of animals are caused by muscles pulling on bone levers; wrote "De Motu Animalium."
1682 Grew studied structure of plants.
1693 Ray classified plants.
1727 Hales investigated respiration of plants.
1743 **Haller,** father of modern physiology.
1744 Reaumur studied insects.
1749 **Buffon** wrote a natural history.
1753 **Linnaeus,** founder of modern botany; classified plants.
1761 Koelreuter studied hybridization of plants.
1764 Bonnet, evolutionist; grouped animals in an ascending series.
1764 Wolff, Friedrich Caspar, overcame the **pre-formation** doctrine.
1772 Rutherford discovered nitrogen.
1774 Priestley discovered oxygen and studied the breathing of plants.
1775 **Spallanzani** disproved spontaneous generation of bacteria and molds and demonstrated presence of living germs in the air.
1789 Galvani discovered animal electricity.
1790 Goethe worked out a scheme for the metamorphosis of the parts of plants.
1794 Darwin, Erasmus, grandfather of Charles Darwin; wrote "Zoönomia," a long poem outlining evolution of life.
1796 Jenner discovered vaccination.
1796 Sprengel studied fertilization of plants.

1800 **Cuvier,** founder of modern comparative anatomy; wrote "Le Regne animal," 1817.
1800 **Bichat,** founder of modern histology.
1801 **Lamarck** invented a scheme for the evolution of animals (by conscious effort and inheritance of acquired characters; not proved).
1801 Treviranus introduced the name "Biology" as distinguished from "botany," "zoölogy," "physiology," "anatomy," etc.
1804 Humboldt studied distribution of plants.
1807 Rumford, Count, demonstrated absorption of carbonic acid by plants.
1811 Bell, Charles, discovered motor and sensory nerve roots; founder of modern neurology.
1818 G. St. Hilaire pointed out unity of plan in animals.
1823 Von Baer discovered the law of embryological development; (all higher forms pass through somewhat similar forms to lower ones in the embryological period).
1830 Brown described cell nucleus.
1833 **Müller, Johannes,** founder of modern comparative physiology. Wrote **Handbuch der Physiologie des Menschen.**
1835 Dujardin studied protoplasm.
1838 **Schleiden** discovered the cell as unit of structure in plants.
1838 **Schwann** discovered the cell as unit of structure in animals.
1839 Agassiz wrote on fresh-water fishes.
1841 Helmholtz discovered rate of nerve impulse.
1853 Mohl studied protoplasm (living substance).
1857 **Pasteur,** founder of bacteriology; studied fermentation.
1858 **Darwin** reported his work upon the origin of species by natural selection and applied evolution to man.
1858 Wallace reported his work upon the origin of species by natural selection.
1858 **Virchow** worked out cellular pathology; founder of modern cellular pathology.
1861 **Schultze, Max,** established protoplasm doctrine.
1863 **Huxley** wrote "Evidence as to Man's Place in Nature."
1863 Lyell wrote "The Antiquity of Man."
1865 Sachs studied structural botany.
1865 **Mendel,** founder of modern genetics; discovered the law of heredity.
1867 Lister worked out aseptic surgery.
1875 **Galton** studied inheritance.
1875 Hertwig, O., studied fertilization.
1880 Koch proved the relation of bacteria to disease.
1880 Laveran discovered malarial parasite (in the mosquito).

1886 Leuckart settled the modern classification of animals; specialized on parasites.
1893 **Weismann** showed that germ-plasm and somatoplasm are distinct.
1893 Zittel wrote most important work on fossils.
1888 Finlay } discovered the relation
1898 Reed } between yellow fever
1898 Lazear } and the mosquito.
1898 Howard discovered relation between typhoid fever and the house fly.
1900 **De Vries,** Correns and Tschermak, all working independently, rediscovered Mendel's law of heredity.
1903 Stiles discovered hookworm in the United States.
1914 Goddard proved feeble-mindedness a unit character.
1915 Stockard discovered influence of alcohol on offspring.

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CHAPTER XXVI

PALEONTOLOGY

JUST as we attempt to read and interpret the history of man's progress in the handicrafts, through the remnants of tools and pottery which are found in various parts of the world, so we attempt to read and interpret the changing conditions which have taken place in the earth's crust by the study of geological and paleontological findings. Geology concerns itself with the changes in the earth itself, while paleontology seeks to build up a meaningful account of the changes which may have taken place in living organisms throughout the past, as demonstrated by their fossil remains (Fig. 245).

There are two general ways in which layers of rock and soil have been laid down. The first has come about by the formation within the earth of great masses of molten substance which was then thrown out by volcanic action. Such masses harden to form minerals and other heat products. If the minerals then become concentrated, they are called ores. All such products formed by heat are known as **igneous formations.**

The second way in which changes have come about is this: Various horizontal soil-layers have been shifted about by climatic changes such as a subsiding of land surfaces and an elevation of the edges of the ocean. This causes the lowered continent to be covered by shallow water, and later, when this condition is again reversed, a layer of sediment is left behind. It is in this sediment that millions of marine-forms of life are stranded. If the sediment hardens, and these marine organisms are safely protected from air and superficial decay, their bodies will be preserved as fossil remains.

Fossil remains are, therefore, observed most frequently in the deposits on the floors of lakes, in peat-marshes, in the deltas of river-mouths, and under the stalagmites in caverns in limestone districts.

The exceptional conditions necessary to preserve organic forms will rarely be found everywhere, so that we must remember that no matter how many fossil remains may be found, only a very infinitesimal portion of the living forms of any given period will become known to us. Then, too, in those which are preserved, most, if not all, of the softer parts of the organism are destroyed, only the hard portions remaining.

The necessity for coördinating the facts found in many and varying ways is of prime importance in the science of paleontology, for without such coördination there is neither sense nor value in its study. This will be demonstrated quite clearly in what follows.

Geology and climatology attempt to explain each other, the former by its effect upon climate, and the latter by its effect on the changing strata which go to make up the earth's surface. In fact, it is the

PSYCHOZOIC	19,000 to 150,000 YEARS	RECENT		
CENOZOIC or (Tertiary) 5% of Geologic Time 5 Miles Deep	Age of Man, Insects and all those Mammals now living All Phyla of Plants including highest flowering Plants.	Quarternary or Pleistocene (pleistos = most + Kainos = recent) Glacial Period Also called Metal age or Palaeolithic ages		Tapir, Pecary, Bison, Llama, Equus, Megatherium, Mylodon. (Gigantic sloths) (Gigantic sloths)
	All trace of Man lost Mammals abundant, many of which are now extinct Pithecanthropus (Pithekos = ape + anthropos = Man.) Found in Java Probably at close of Pliocene Period	TERTIARY (Age of Mammals) 2,900,000 years	PLIOCENE (pleion = more Kainus = recent	Equus Beds (Equus = Horse) Equus, Tapirus, Elephas Pliohippus Beds Hippus = Horse Pliohippus, Mastoden, Bos., etc
	Primates Had made great Progress, Ancestral Stock of gibbons Dryopithecus. (Drus = Tree + Pithekus = Ape) Large Anthropoids Increase in higher flowering Plants		MIOCENE (meion = less Kainus = recent) (Not found in England)	Miohippus Beds Miohippus, Diceratherium (2 horned), Thinohyus. Oreodon Beds. (Orae = Mou a in + odont = Tooth) Edendates. Hyoenodon, Hyrocoden. Brontotherium Beds. (Bronte = Thunder + Therion = Beast) Mesohippus, Menodus, Elotherium
	Mammalian Forms abundant Many now extinct Increase in flowering Plants		EOCENE (eos = dawn Kainus = recent)	Diplacodon Beds Epihippus, Amynodon. Dinocerus Beds. Tinoceras, Uintatherium (Deinus = terrible + Keras = Horn) Limnonyus, Orohippus, Helaletes, Colonoceras. Coryphodon Beds. Eohippus, Monkeys, (Coruphe = Summit + odont = Tooth Carnivores, Ungulates, Tillodonts. Rodents.
MESOZOIC or (Secondary) 12% of Geologic Time 11.5 Miles Deep	Birdlike Reptiles Flying Reptiles Toothed Birds First Snakes. Bony Fishes abound; Sharks numerous; Rapid increase of Lower Flowering Plants	CRETACEOUS (Chalky) (Age of Reptiles) 5,000,000 years		Lignite Series Hydrasaurus, Dryptosaurus
				Pteranodon Beds. (Pterodactus = winged reptile + anodon = Toothless) Birds with Teeth, Hesperornis. Ichthyornis, Mosasaurs Pterodacthyls. Plesiosaurs.
				Dakota Group
	First Birds, Giant Reptiles, Ammonites, Clams and Snails abundant Ferns, Cycads, and Conifers.	JURASSIC (Limestone as in the Yura Mts. 2,000,000 years		Atlantasaurus Beds Dinosaurs, Apatosaurus. Nanosaurus, Turtles, Diplosaurus.
	First Mammal Found. (a Marsupial); Sharks reduced to new Forms, Bony Fishes appear Ferns, cycads, and Conifers.	TRIASSIC (Three layers = Sandstein Muschelkalk and Keuper) 2,000,000 years		Connecticut River Beds. Dinosaur Foot-prints, (Amphisaurus) Crocodiles, (Belodon).

Fig. 245.

Composite Palaeontological Chart, compiled from many authors, showing geological strata and fossil-forms found in each. It will be noted that the number of years assigned each stratum varies from any given amount to ten and even a hundred times that number. The student must therefore realize that all such estimates are only guesses. What he must know is the relative percentage of time and the relative percentage of depth of each layer and speak only in terms of "eras" and depths.

Professor Osborn has just described *(Natural History,* for November-December. 1921) a Tertiary man living long before the ice-age.

changing climatic conditions which give us the terms "ages" or "periods," such as the **carboniferous age** and the **glacial period.**

If the deposition of the earth's layers has been laid down by water and air, the various strata show such causes by forming a coarse sand-layer, followed by a layer of finer sand or mud. Or, two sandy layers will be found separated by thin layers of muddy shale, the exact formation depending upon the velocity of both sand and water.

Or, there may be mechanical and chemical changes which produce beds of rock sand or gypsum between beds of marl. Likewise, organic

PALÆOZOIC (Primary) 19% of geologic time 18.5 Miles Deep	Earliest of true Reptiles, Amphibians, Lung Fishes; Fringe Fins; First Cray Fishes, Insects abundant; Spiders; Fresh Water Mussels. Ferns, Calamites, Lycopods, Cycads, Conifers.	CARBONIFEROUS (Age of Amphibians) 3,000,000 Years		Permian Red Sandstone, etc Magnesian Limestone
				Coal Measures. First Reptiles (?)
				Subcarboniferous Carboniferous Limestone
	First Amphibians. (Froglike Animals) Sharks; Ostracophores. First Long Shells (Snails) Mollusks abundant First Crabs Ferns Calamites Lycopods Cycads Conifers	DEVONIAN (Age of Fishes)		Corniferous Schoharie Grit
	First truly terrestrial or air-breathing animals; First Insects, Corals abundant, Mailed Fishes Probably some Land Vegetation	SILURIAN	Upper Silurian	Sandstones, Shales, Some Limestone
	First Known Fishes: Ostracophores: (Fishes having no jaws, Segmented Backbones or Limbarches & Forepart protected by bony Plates Cartilaginous Skeleton; Brachiopods, Tribolites; Mollusks, etc.		Ordovician or Lower Silurian	Slates, Sandstones, Volcanic Rocks, etc.
	Invertebrates only. Probably some Higher Algae	Cambrian	Primordial	Slates Sandstones, etc
ARCHÆN 64% of geologic time 62 Miles Deep	Simple Marine Invertebrates Probably very simple Algae	ARCHÆN	Huronian	Slates, Volcanic Rocks, etc No Vertebrates Known
			Laurentian	

Fig. 245.

activities may have their influence as shown by the fine beds of coal succeeding layers of sand, or by a layer of large fossils imbedded in limestone.

As there is a tremendous pressure of the superincumbent layers upon the underlying strata, the lower layers as well as their fossil contents are often crushed and injured. Extreme care must, therefore, be taken to interpret one's findings. One can readily grasp what such pressure would accomplish in the delicate layers of shale (called paper-shales), which range from sheets as thin as paper to layers of such sheets fifty feet or more in thickness.

A study of the fossil remains of plants and animals should show us in what order these organisms lived and followed each other in times long past, and it is usually conceded that they do; but, it is not an uncommon thing to find an earlier fossil layer lying above a later one. Geologists explain this by saying that changes have again taken place which reversed these lower beds, or thrust earlier strata between other layers. All this complicated arrangement lends itself to deceptive interpretation. For example, those who oppose the usually accepted geological evidence of "periods of time" and "successive ages" say that the arrangement of the various strata is so deceptive, that it can only be explained by a world upheaval of some kind, and that, therefore, no evidence of successive ages is worth anything.[1]

An interesting example of the order in which certain strata have been formed, is found in instances where trees and their stumps are found lying in a more or less semiupright position. Often the stump part and roots still lie in their position of growth, or at least they lie in a deeper stratum than the upper and less heavy portion. Such trees were either pushed over by a stream of water, or carried along by the stream. The heavier end became caught or weighted, and sank, while the upper end remained in a slant position in the direction of the current. It is, of course, also possible that the trees were entirely submerged while still growing. In the latter case, however, the rate of sand deposit must have been sufficiently rapid to lay down an accumulation of at least forty feet (enough to cover the erect tree) before the wood decayed.

Former regions have been identified by the occurrence of great quantities of driftwood found in the strata, as having been quite close to land; while differences in climate are evidenced by the finding of tropic plant and animal remains in cold regions, and arctic plants and animals in tropic regions.

Migrations of plants and animals from one region to another are demonstrated by the finding of fossil remains in different types of strata in different ages.

[1] G. McC. Price, "The Fundamentals of Geology."

However, no one can tell the number of years required to lay down the various strata any more than he can tell how many years elapsed to form the intervals between such laying down; and these intervals no doubt were often much longer than the time it took to form the strata.

Intense cold or heat, resulting from a climatic change, undoubtedly killed many organisms which were unable to adapt themselves to the changing conditions of the past; while mountain ranges, becoming elevated, cut off the moisture-supply of others who went the same way.

The glacial period is considered synonymous with the **permian,** and represents the extreme of cold, while the **tropical period,** the extreme of heat, is represented by **coal beds** (Fig. 245).

The mechanics of adaptation of living organisms to new climatic and environmental changes has given rise to much speculation.

Lamarck thought that the organism was directly affected by any change in environment and that this change then affected the germplasm so that the change in the parent could be inherited by the organism's offspring, and thus result in a permanent racial change.

Others taught that both somatoplasm and germplasm are simultaneously affected. This theory is known as that of **parallel induction.**

Darwin, like Lamarck, believed that small environmental changes became large ones as they were successively inherited. In fact, this was held by nearly all the early workers since the time of Darwin. But, as no evidence has been forthcoming which could explain how such environmental changes could affect the germplasm and thus be inherited, biologists are inclined to hold with Professor H. H. Newman, that "external factors accelerate or retard processes that were already under way in the germplasm, so that the response appears to be something new in kind when it is only the result of a sudden acceleration of a character evolution already under way. Whatever be the underlying mechanism involved in adaptive changes, there is no hope of explaining adaptations on the Darwinian basis, through the selection of the best out of a vast area of purely fortuitous variations; for if the historical study of vertebrate evolution reveals one thing more clearly than any other, it is that evolutionary changes are ordinarily progressive, and determinate in character, and that in many respects these ordinary processes of evolution are independent of each other and of environmental changes."

This means that we need not hold that animals always adapt themselves to their environment, but that they can migrate to environments which are best suited to them. And there is ample evidence to show that such migrations took place quite often. Some of these are shown by the land-bridges (over which animals passed) now destroyed, which connected islands and continents with each other. The animals were then shut off from their original home by the destruction of the bridges. Such animals are said to be **geographically isolated.**

Not only have animals migrated, but as already stated, the climate itself migrated. This is shown by the fact that the marine and glacial coverings of the land's surface took place at much later periods in some places than in others.

To return to the fossils themselves, it is necessary for the student to understand the various forms in which fossil remains come down to us. Bones may be buried in silt which then hardens. Later, water, containing minerals, may make its way through the silt and bit by bit dissolve the bone, and deposit a mineral in its place. This is **petrification.** The shape and form of the bone remain intact, although the original bone-substance is replaced by a mineral.

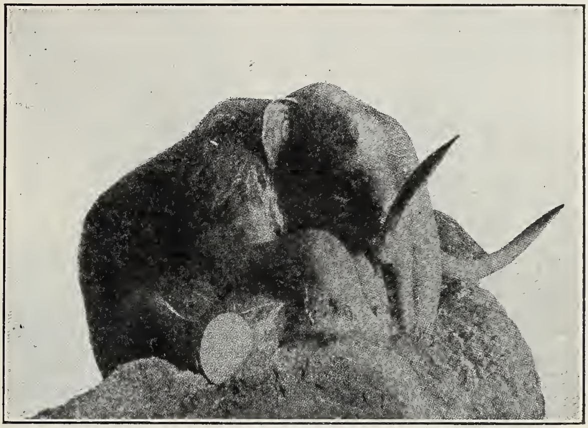


Fig. 246.

Mammoth found frozen in Siberia. The skin is mounted in the museum of Petrograd in the posture in which it was found. (From Lull's "Organic Evolution," by permission of the Macmillan Co., Publishers.)

Or, an organism may retain its form long enough to have the surrounding substance completely encase it and harden. As time goes by the organism is dissolved and disappears, while the hollow space it occupied remains. Such hollow forms, in the shape of organisms no longer present, are called **molds.** Investigators fill these molds with a material such as plaster of paris (which hardens easily) and obtain a **cast** of the original organism.

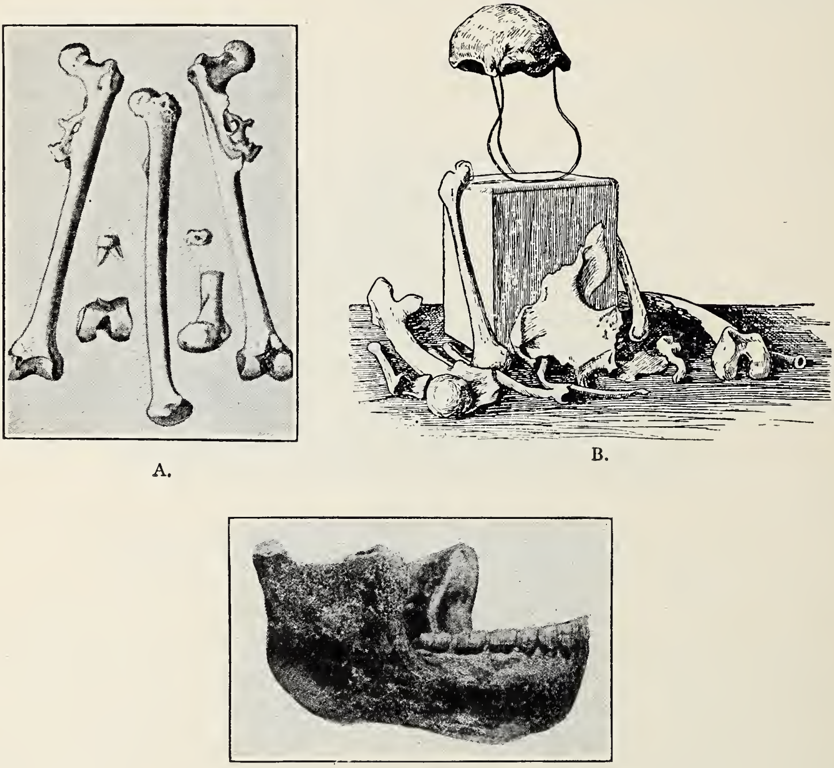
Then, too, as stated above, the tremendous pressure of the upper layers may crush the fossil forms beneath, or the minerals which caused petrification may be re-dissolved, so as to expose the fossil remains to a condition which destroy them, and this may happen after they have been so encased for thousands of years. Weathering and erosion may also expose fossils to the harmful effects of the weather.

When very definite fossil remains are always found in certain strata, they are often called "index fossils," as such fossils can be used to determine the place and period of the strata from which they are taken.

One of the most interesting finds in 1901 was that of an ancient animal, whose species is now extinct, that of a mammoth found frozen in the ice of Siberia (Fig. 246), whose flesh was in excellent condition.

In oil-bearing sands many excellent fossil specimens have also been well preserved.

But the fossil remains, which have excited most discussion and speculation, are those which are supposed to have belonged to human beings higher in the grade of life than the highest apes we now know, and yet



A. B.

C.

Fig. 247.

A. Remains of *Pithecanthropus erectus;* the single femur shown in different aspects.
B. Remains of the Neanderthal man in the Provincial Museum at Bonn.
C. The Heidelberg Jaw.
(A. From "The Open Court," B. from "Weltall V. Menschheit," C. from Bryce after Schoet Ensack.)

distinctly lower than man. Authorities, however, disagree considerably as to what type of being these bones represented, some insisting their possessor was human, and some that he was not.

One of the most important of these "finds" (1891-1892) is that of a part of a skull, two teeth, and a femur (Fig. 247, A). These parts lay at some distance from each other, so that we cannot be certain that they belonged to the same individual, but it is assumed they do. The shape of the femur indicates that its owner walked in an erect position and was about as tall as men now are. From the parts thus found a so-called "reconstruction" was made to show what the reconstructor thought the individual must have looked like. The name **Pithecanthropus erectus** is applied to the individual who once possessed these bones (Fig. 248). The bones are presumably from the early **Pleistocene period.**

At another time a lower jaw with its teeth was found near Heidelberg in Germany (Fig. 247, C). As the teeth are not ape-like, but approach those of man, the individual who possessed them has been called **Homo-heidelbergensis.** The fossil remains of various animals found in the same region with the Heidelberg jaw give us the age of this find as that of the **second interglacial** period, which means that this jaw is only about one-half the age of **Pithecanthropus erectus.**

In 1856 there was found in Prussia the skeleton of what is called the Neanderthal man (Fig. 247 B, and 248), or **Homo-neanderthalensis** which comes from about the fourth glacial period, so that it is about one-third the age of the Heidelberg man.

Fig. 248.

Restoration of prehistoric men. Left, *Pithecanthropus erectus*; middle, *Homo neanderthalensis*, modeled on the Chapelle-aux-Saints skull; right, Cro-Magnon man, modeled on type skull of the race. (From the original busts of, and by courtesy of, Professor J. H. McGregor.)

Then in France and Wales a number of skeletons have been discovered in which the skull is narrow and the face broad, something like that of the Esquimaux. The cheek bones and chin are also prominent. Professor J. H. McGregor has molded busts in accordance with his idea of what such men must have looked like (Fig. 248).

There is no connection whatever between these various forms, so we cannot in any way prove that they are a genetically continuous series. All conclusions built upon these finds must, therefore, be purely conjectural.

From the evidence presented here, we note the fact that many present-day forms of both plants and animals are unlike their ancestors. We are, therefore, confronted with four possible explanations of why they are different: (1) that present-day forms are the lineal descendants of ancestral forms unlike themselves and that all new forms with ever increasing complexity spring from older ones; (2) that new forms different from the older ones have been created at different periods; (3) that all forms were brought into existence at about the same time, but due to a great world upheaval the fossiliferous strata have been so confusedly arranged that, while all fossils are of one age, it is our mistaken interpretation which makes us believe they are of different ages; or (4) that organisms came into existence which, at the time of their origin, had the possibility of change placed within their germ-plasm, but which had to await the proper conditions of food and environment before they could come forth to produce present-day forms.

If it be accepted that any present-day forms are different from their ancestors, and that these new forms can produce offspring capable of transmitting that change to their posterity in turn, we must speak of an **evolution** as having taken place.

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CHAPTER XXVII

EVOLUTION

THE student must not forget when discussing evolution that this term means only that some present-day forms have become unlike their ancestors, and that such difference is then transmittable—in other words, **that it has affected the germ-plasm.**

Evolution as it applies to the individual is, therefore, the name given a **process** by, and through, which an organism evolves or changes into a different type of being from its parents.

In the chapter on genetics, we have seen how all offspring vary to a small extent, not only from their parents, but from each other. When such differences are slight, they are called **variations** and the organisms possessing them are known as **varieties.** When such variations become sufficient to set aside the new organism as a quite different type from its parents, the new types are known as different **species.**

It will be noted that this is quite vague; for, what one man may consider a difference sufficient to form a new species, another may not. There is, therefore, no good definition of the term **species.** Biologists disagree to a very marked extent as to what it means.

Members of the higher groups of animals are often considered as belonging to the same species if they can inter-breed and give birth to fertile offspring in turn. But, if we are to accept this definition, there never can be any strictly new species; for, if animals can inter-breed, their offspring will belong to the species to which their parents belong, and if they cannot, there will be no offspring.

Then, there are those who take the position that only those individuals form true species which **always breed true.** If we accept this definition, it may be said that whenever a so-called new-form or **mutation** (as it is called) comes forth, such new form is in reality only the return of some ancestral type, which has been formed by the meeting of an egg and a sperm, both of which carried recessive characteristics. From this angle one may always explain new species as being old ones, again coming forth.

However, species generally mean **groups of individuals who possess similar outstanding characteristics, which characteristics can be transmitted to their offspring.**

First, then, in discussing evolution, one must be convinced that new species really do come into existence, otherwise there can be no evolution. Practically all biologists now hold that new species do come into being, which means that they accept evolution as a **fact.** There is, however, a vast difference of opinion as to the limitations within which evolution operates, both in the individual and in the race, as well as to the method by which evolutionary changes come to be what they are.

Secondly, if all present-day forms have sprung from ancestors unlike themselves, the question arises as to whether all the different phyla sprang from one original living being (whether evolution is **monophyletic** or **monogenetic**), or whether there were numerous "first forms" from which all successive forms spring (**polyphyletic** or **polygenetic** evolution).

Having settled for ourselves whether evolution is a fact, we set about trying to find a theory which will account for that fact.

Only two great theories have been advanced. One by Charles Darwin, known as **Darwinism**, or **Natural Selection**, and the other by Korschinsky, and De Vries, known as the **Saltation** or **Mutation** theory, or **heterogenesis.**

Darwinism holds that, as we have seen, the offspring of a single pair of flies will be almost six billion in ninety days if all eggs were to hatch. It follows that were such increase to continue in all animals and plants, the food-supply would soon become exhausted. There must, therefore, be a **struggle for existence** to determine which plants and animals are **fittest to survive.**

Everyone has noted that millions of eggs, maggots, and insects never reach the adult form of life because they are eaten by various animals. The number of flies and other insects is, therefore, dependent upon the number and activity of their natural enemies as well as their own physical ability to avoid such enemies, together with their ability to obtain a sufficient supply of food and water for themselves.

It follows that there will be a **struggle** even among the same group of organisms for food and water, while the whole group must struggle against their many natural enemies. Nature, through such struggle, selects the strongest and most active (as these are the only ones which will not succumb to the struggle) to carry on the race. The particular characteristics which make it possible for plants and animals to survive in this struggle for existence, are said to have a **survival value.**

Darwin accepted **variations in all living organisms** as a fact, and built his theory on that fact. He contended that useful variations by possessing a **survival value** were transmitted to the offspring of such organisms, so that each succeeding generation received the advantage of its parents' **acquired characteristics.**

However, it is generally held now that acquired characteristics are practically never inherited, and that natural selection only explains why certain organisms did not die and others did. It cannot explain **the origin** of new species.

Darwinism is based on the assumption that very **minute changes** are constantly taking place in the organism. These changes have an effect on the germ-plasm of the individual, thus altering it and causing the change to be transmitted. For example, a giraffe by constantly eating food from trees, finds it necessary to reach higher and higher. This stretching of the neck will, then, in each generation cause the young giraffes to be born with a slightly longer neck.

If such a change makes the individual better able to **adapt** itself to its surroundings and thus gives it an advantage in the struggle for existence, it is said to be a **selective factor.**

The **mutation theory,** contrary to the Darwinian, insists that sudden jumps, or great changes, take place, which are then transmitted. This theory is based on the fact that there are in nature so-called "freaks" or "sports" which suddenly spring forth.

The crooked-legged sheep is the classic example. A New England ewe gave birth to a peculiar, crooked-legged ram. The shrewd Yankee farmer, who owned the sheep, saw in this crooked-legged ram an animal that could not jump fences, and so kept it. The **crooked-leggedness** proved to be a **Mendelian dominant character** which is transmitted from parent to offspring. There are now great numbers of the descendants of this single New England crooked-legged ram, which are in turn crooked-legged.

Such mutations can be explained by assuming that the recessive characters in egg and sperm have met after lying dormant for many centuries.

In fact, there are a number of examples of characters lying dormant and being carried on from parent to offspring, only coming forth at certain times when the mating organism likewise has a similar dormant or recessive character. For instance, many mullein plants will, in certain years, suddenly produce longer leaves than is normal for that plant, thus showing that the cause of the longer leaves must be in the germ plasm of the varying plants. For, if such were not the case, there would not be so many to develop longer leaves in the same generation.

In other words, this means that there is a peculiar arrangement of genes in the chromosomes of the mating-plants, and these genes have united to cause a similar abnormal development in all those plants which spring from similar zygotes.

It is for reasons of this kind that biologists have come to the conclusion that environment does not change the organism to any appreciable extent in its genetic value, but, that whenever changes come forth, these are due to changes in the germ plasm.

To the two great theories mentioned above, there have been added at various times what might be called sub-theories or part-theories to account for certain developmental characteristics. The most prominent of these is known as **Orthogenesis. Eimer** and **Nägeli** are its sponsors. Orthogenesis means that there is something in the organism which, once a line of development has begun, will enable the organism to continue in that certain line of development even though it kill the individual. An example, which comes to mind, is the teeth of rodents. These, when the animal becomes older and is unable to chew the hard substances it did when young, continue to grow with the same undiminished vigor that they did when they were constantly being worn down by contact with hard substances, so that they may, as in the beaver, force the mouth open and starve the animal to death.

But orthogenesis must be explained, and various reasons have been suggested to account for it, the reasons varying according to the "philosophy of life" of the one who is doing the explaining.

Those who hold that all things are to be explained in terms of physics and chemistry, attempt to explain orthogenesis in physicochemical terms. Those who hold that there is an inner driving force in all living matter which cannot be explained by physics and chemistry, insist that it is this inner driving force, or "vitalistic principle," which alone can account for it.

Both sides, however, agree that the cause for this development is not in the organism's environment, but must be sought for in the organism itself. As Professor Borradaile puts it, "the part of the environment is to decide which of the experiments of the organism are failures." And there is sufficient evidence to accept his statement. For instance, the fertilized egg-cells of nearly all the higher organisms are quite alike, yet they develop quite differently. And they retain this difference in development, even if the egg is transplanted into the body of a different kind of animal and is there allowed to develop to maturity. There must be a difference in the environment of the organs within the bodies of different animals, yet the egg grows on as it would have done under its normal environment.

When such definite direction takes place it is called **purposiveness.**

The objection raised against the physico-mechanists (those who believe that all things can be explained in terms of physics and chemistry) by those who do not hold to their point of view (vitalists), is that the body cannot be accepted as a machine in any true sense of the word. A machine produces a very definite and single type of work, while the living organism has all its work directed toward its own welfare, and unlike any machine known, can, when it is injured, direct its entire working system toward repairing itself in addition to continuing its regular work. It not only heals the wound inflicted, but actually grows new material, as we have seen by the regeneration experiments in **Planaria** and **Arthropoda.**

Then, too, there is a decided chasm dividing living and non-living matter; so much so, that it is a common dictum of Biology that absolutely no life can come from non-living matter. There is no single case on record of any organism coming into existence except as the offspring from some other organism.

However, as we know living things did not exist always, there must have been a time when they did come into existence. The physico-mechanists say, that while no living matter comes from non-living to-day, yet, as there must have been a time when it did, we must assume that different conditions once held sway from those we now know.

But, such being the case, we break the most important law known to science—that of **continuity.** It is for this reason that it has been said, that the breaking of this law of continuity is the only heresy known to evolutionary science.

The theory that life always comes from life is known as **biogenesis,** while the theory which holds that life can come from non-living matter is called **abiogenesis.**

It will be noted that the evolutionary theories so far discussed have only taken the **physical side** of the individual into consideration to the entire neglect of the mental and intellectual.

It was **Alfred Russel Wallace,** co-founder with Darwin of the natural selection theory, who saw this quite early, and insisted that the psychical or mental side must also be considered if we are to form truly valid conclusions. He contended that once mentality enters, as it does in man, such an organism could use this mentality to set aside or change the physical selection which nature carried on. In other words, the earlier evolutionists were interested in the **structure** of nerves and nerve elements, while Wallace saw the necessity of taking the **thought** which is carried by the higher nerve centers into consideration.

It is well for the student to know both the evidence adduced in support of evolution and evolutionary theories, and the objections which have been hurled against it. We have, therefore, summed up the arguments of both sides, whether such support and objections are always conclusive or not.

EVIDENCES FOR EVOLUTION

1. **Paleontological.**

(a) Many new kinds of plants and animals are found in each successive strata as shown by their fossil remains.

(b) The later organisms are more complex than earlier ones.

(c) The more recent fossils prove that they are quite closely related to the modern forms now living.

2. **Genetics.**

Breeding experiments, as well as observation, prove that all organisms are constantly varying, and that constant variations in the same group of organisms are transmitted to succeeding generations.

3. **Comparative Anatomy.**

The similarity of structure in different individuals is precisely what would be experienced if evolution did take place.

Homology (similarity of structural development) is to be regarded as a sign of relationship as it is assumed that in such cases little or no structural change has taken place in times past. Contrariwise, organisms which are quite dissimilar in structure are assumed to have diverged many years ago.

4. **Comparative Embryology.**

(a) Likenesses between embryos of different animals are assumed to demonstrate a close fundamental relationship and a common ancestor. An example often quoted is that of **Sacculina** (Fig. 212), a parasite on the abdomen of the crayfish. This parasite is merely a rounded, pulpy mass with no clearly defined structure except a little root-like projection, which extends into the body of the host to absorb the fluids. The embryo of **Sacculina**, however, is a very definitely shaped three-cornered little organism with jointed legs and all other necessary features which bring it under the crustacean classification. In fact, it is practically a degenerated barnacle.

(b) All higher forms of vertebrates possess so-called **gill-pouches** during the embryonic stage, although the higher forms do not retain them in the adult stage. This would lead to the assumption that the common ancestors of vertebrates must have been fish-like.

(c) According to **von Baer** and **Haeckel**, all animals during the embryonic period pass through the adult forms of the race to which they belong, thus presenting conclusive evidence of the history of their descent.

5. **Comparative Physiology.**

(a) Animals, which are closely related genetically, have a somewhat similar blood-composition, as proved by the fact that the blood of one such related animal can be successfully transfused to another without harm.

(b) The test described in Chapter XIV by which human blood can be differentiated from that of many lower mammals, does not differentiate human blood from the blood of the higher apes.

6. **Geographical Distribution.**

Animals such as marsupials (pouched animals), which have as much in common structurally as the Australian kangaroo and the American opossum, while yet quite unlike in general appearance, can only be accounted for by taking into consideration the geological evidence for a land-bridge which once connected Australia and America. The two animals having had the same ancestry, changed their appearance because of a changed geographical environment, although their general structure has remained quite as it was.

There are no native ungulates in Australia, although there is no reason why there should not be if other than evolutionary methods have been factors in producing new types of animals.

Or, again, one finds, for example, on the west coast of South America, peculiar animals found nowhere else in the world, while on the neighboring islands there are animals resembling those on the coast of the continent both in structure and habit, yet sufficiently different to be called new species.

7. **Natural Selection.**

This is an attempted explanation of why present-day forms are what they are, by showing that food is never equal to the possible rate of increase in living forms. Such lack of food causes a struggle for existence, through which struggle the weakest (the ones being least adaptive) go down, while the stronger (those best able to adapt themselves to their environment) survive.

Natural selection describes the causes which have prevented surviving forms from becoming extinct.

OPPOSING ARGUMENTS

The arguments which are usually brought forth to oppose these evidences for evolution are as follows:

1. **Paleontology.**

(a) The different kinds of plants and animals found in various geological strata can only demonstrate that similar organisms were either larger or smaller than others, or varied in ways which can be accounted for by a difference in the temperature and food supply of different ages. Examples of this are the horse and mammoth. Then, too, paleontologists insist that their finds can only be explained by assuming that acquired characteristics are inherited, although experimental evidence seems to point against this being true.

(b) The so-called increasing complexity on the part of so-called "younger" fossils as compared with so-called "older" ones, may always be explained by assuming that Mendelian recessive characteristics have again come forth, and that consequently the so-called "new forms" are really a return of old ones.

(c) Recent fossils are like modern forms because the climatic changes and the food supply have not varied much during the interval between our own time and the time when the prototypes of these recent fossils lived, and examples of so-called older forms (those which lie above the recent forms) can be considered evidence for this statement.

(d) Those who insist on experimental evidence which is always under the control of the experimenter, say that fossil-remains furnish us only with "descriptions" of what is found. It is a "dead" account. It can never give us an explanation. Explanation and interpretation can only come through our logic. Paleontological evidence is, therefore, all **logical** and not experimental. A strictly scientific explanation from the experimentalist's point of view must also present experimental evidence. This has not been, and cannot be, done in paleontology.

2. **Genetics.**

Inherited changes can always be referred back to ancient Mendelian recessives meeting, and thus producing a "past" type. No strictly "new" types can ever be formed because the chromosomes never die (so long as there are living offspring), and all that ever happens is that some part of them is thrown out. But, from what is known of Biology, it is impossible to add anything to the offspring which is not already present in the chromosome content of the germ cells.

3. **Comparative Anatomy.**

Similarity of structure by no means proves relationship, as shown by examples of **convergent evolution**, where two quite dissimilar structures come to look alike in various aspects, due to similar functioning. Witness such experiments as Carey's in which bladder-muscle was converted into beating heart-muscle by causing the bladder to simulate heart-conditions.

The argument from comparative anatomy holds good only if one accept the dictum that "structure determines function," while the experiment just mentioned shows that function determines structure, once one has the material with which to work.

4. **Comparative Embryology.**

(a) Any organ not used is likely to degenerate. This accounts for **Sacculina** degenerating when it assumed a parasitic habit where it no longer uses the various organs it once used. This is not remarkable, and if it proves anything, it proves only that an organism can lose something it once possessed, though it by no means proves that what we have been considering a more complex organism, can arise from one that is less complex.

(b) The so-called gill-pouches demonstrate only as in (c) that vertebrate forms pass through similar stages of growth and not that one springs from the other.

(c) If the Haeckelian law is to hold good, that embryos pass through the adult stages of the race to which they belong, we are confronted with some unacceptable conclusions. For instance, only the human being walks in an entirely upright position. In man alone there are in the developing brain three complete bends which remain throughout adult life. It is assumed that only his upright position can account for the third bend, which brings the cerebral hemispheres back over the brain-stem. But in the chick, and in practically, if not all, vertebrates, these three bends take place in the embryo. It is later that at least one, and sometimes two, of the bends disappear. We must, therefore, assume that frogs, chicks, lizards, etc., once walked erect like man, an assumption that not even the most ardent defenders of the Haeckelian law will admit.

5. **Comparative Physiology.**

(a) Similarity of blood-composition in quite similar forms is to be explained again on the principle that all similar forms go through a similar development, and that with similar food and temperature, the blood must necessarily be quite similar because it must draw its component substance from the same food material.

(b) Since the blood of a hybrid-form, such as the mule, reacts differently from that of either of its parents, we do not know, until further research brings forth more proof, that similarity of reaction in blood-tests is a valid test of relationship.

6. **Geographical Distribution.**

This, like natural selection, can only show why some organisms survived. It throws no light on origins. It can show how parts of an organism may be lost, but not how additional complexity has come.

7. **Natural Selection.**

This explains nothing of importance. It fails utterly to explain the degeneration of useless organs, and why variations of great magnitude do not occur more often, as well as why and how a simultaneous variation in different parts of the body takes place to improve a definite organ.

8. **Psychology.**

All the evidence evolutionists adduce to prove their arguments is invalid because they take only the physical side of the organism into consideration, forgetting the most important part—the mental.

9. Logic.

We have been reversing the order of things, by forgetting that, if a tiny cell or organism has the ability or potentiality of becoming a highly complex animal, it must be much more complex than the later organism into which it is to grow. For, surely the smaller an object may be, which can contain all that it is later to become, the greater in complexity it must be. And, if such a tiny object is so intensely complex, it could not have suddenly sprung into existence without an intelligence of some kind arranging it.

10. Physics.

The student of depth has been driven into out-and-out skepticism of anything being true in science, or has gone over entirely to mysticism, because he cannot overcome the obstacle which the acceptance of the laws of the different laboratory sciences place in the way of his biological findings. For example, physics tells him that no more work can be obtained from a machine than is put into it, and that nothing can rise higher than its source. Then the evolutionist tells him (in contradiction to these laws) that more complex forms come from those less complex. This belies both laws, for intelligence is certainly something higher, and more than non-living matter. And intelligence cannot be explained in terms of either physics or chemistry.

If it be told the student that the energy of the sun furnishes the energy which can do all these things, and that there is a law known as the conservation of energy, he will read the statement of various eminent physicists who tell him that the sun's heat will gradually become less and less, finally becoming entirely dispersed. Consequently there will not be as much as there once was, and the law is broken. This brings him back to the place from which he started. "How did the energy and the potentiality of a simple organism become complex, and how did the developing intelligence become what it is, unless it got it from something still greater?"

11. Language and Intelligence.

If it be proved that plants and animals have arisen in an ever-ascending plane, how account for articulate language and intelligence (true ability at thinking which is then expressed in words)? Can this **psuchus** or **psychon,** or real intellectual part of man, have come from anything less than a still greater intelligence?

12. Continuity.

As was shown in the chapter on the history of Biology, the very foundation of science, as now understood, is based on the law of continuity, namely, that the laws of nature never vary. Yet we find all biologists agreeing that the law of continuity has been broken, by the fact that living forms must have once sprung from non-living, a condition now no longer true. This is the great "heresy" of evolutionary science. As life and mentality do not now operate as they once did, when, where, and how did they begin?

13. No Satisfactory Theory of Evolution.

No theory of evolution yet propounded is satisfactory because none has satisfied the requirements set forth above.

14. Impossibility of a Satisfactory Physical Explanation.

There exist certain rays, known as infra-red and ultra-violet, which no human eye can see; yet, these rays can be proved to exist by the physicist. If the ultra-violet rays are thrown upon a group of brown ants they will immediately scatter quite hurriedly, thus demonstrating their ability to sense rays which man cannot.

Now, it is probably from such evidence as this that one biologist, at least, draws the conclusion that just as there are undoubtedly thousands of colors which no human eye can see, and thousands of sounds no human ear can hear, so there must be thousands of factors in every explanation which the human mind cannot grasp. This being true, it follows that, if we can find any explanation which is plausible, and which fits in with every nook and crevice of our mind, we know that such a theory is not likely to be true, because there are thousands of points that we must necessarily have neglected to consider due to our sheer intellectual inability. Thus even the most plausible arguments are vitiated.

SUMMARY

We have presented practically all of the important arguments for and against evolution itself and the various theories which attempt to account for it, because it is just as essential for a well-educated man to know the opposing arguments in any given case as it is for him to know the supporting ones. The theories which the student is to accept are those which he finds sufficient evidence for in his work throughout his laboratory course.

Regardless of what one may believe that the evidence has brought forth, all biological workers must accept evolution as a scientific hypothesis, though this does not mean that they must accept any of the theories propounded to account for it. The above statement is true, because there is much more evidence to show that an evolution has taken place than there is to show how and why it took place.

Then, too, the student must note the difference between the cause

of evolution (which the various evolutionary theories try to explain) and the **course of evolution.** This latter is only a description of what has been found, as, for instance, the charts which show the various fossil-remains of what are considered the ancestors of the horse and mammoth. Such charts, of course, **explain** nothing.

The Darwinians originally held to the doctrine that all variations must possess some function of a survival value, but we now know that characters which are a decided hindrance in the survival sense, are inherited and passed on from one generation to another just as readily as those which are of value.

Two different types of organisms may often grow to be quite alike, or at least certain organs may develop so as to appear alike if they function alike. This growing alike is known as **convergent evolution.** Individuals originally structurally alike, which later become dissimilar, are said to do so through **divergent evolution.**

From what has been said above, one is likely to agree with the writer who said that every biologist seems to have his own pet theory to account for the evolutionary process.

Notwithstanding this fact, one must, however, have some kind of a gauge by which to measure the plausibility of a proposed theory. Otherwise there is not even an approach toward finding whether any given evidence is of value.

It is to assist the student in forming such a gauge that the following seven questions are here tabulated. These must be answered by any theory which is to win complete and final acceptance.

CRITERIA FOR A SATISFACTORY EVOLUTIONARY THEORY

These questions refer to organic evolution in its widest signification, as referring to both the individual and the race.

(1) How did life originate?

(2) How can a more complex individual develop from ancestors which were less complex?

(3) How can an organism adapt itself to its surroundings?

(4) What causes the so-called mechanically directed type of variations known as orthogenesis?

(5) What causes the series of the many undoubtedly purposive adaptations?

(6) What causes the factors of heredity to behave as they do?

(7) What factors can account for mentality and intelligence (which are non-physical things) arising from physical and non-mental matter?

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CHAPTER XXVIII

CLASSIFICATION

IT has already been shown that one may classify living things as to structure or function, that is, as to **anatomy** or **physiology.** The early naturalists felt that the most important thing in the study of living matter consisted in finding names and assigning definite places for every distinct individual. A little later morphology, or anatomy, was considered most important. Still later physiology, or the way an animal performs vital activities, was the all-important thing. Then with the discovery that urea, an organic compound, could be manufactured in the laboratory, much stress was laid upon chemistry. Formerly it was quite common for naturalists to look for **differences**, in order to classify an individual, while now we look primarily for **similarities** in order to understand the close relationships which bind individuals into a common group.

Fig. 249.

Carl von Linne, 1707-1778. From G. Stuart Gager's "Fundamentals of Botany" by permission of P. Blakiston's Son & Co., Publishers.

Classification is now no longer the prime factor in the study of Biology, and men, who are interested only in assigning names and groupings, are not considered scientists. It must not be forgotten, however, that there could be no science possible, and biologists would be unable to discuss their work intelligently with each other unless some method could be found by which each would know what the other was talking about.

It is, therefore, well to know several of the important naturalists whose names are most intimately associated with this particular phase of Biology.

John Ray (1627-1705), an Englishman, was the first real systematist.

Following him came **Carolus Linnaeus** (Carl von Linne, 1707-1778), who is in reality the founder of our present method of classifying. In fact, one of the distinguished honors that may come to a botanist is to be elected a Fellow of the Linnean Society. Linne's important work was his **Systema Naturae,** consisting of twelve volumes, which appeared between the years 1735 and 1768. There was a thirteenth volume, added after his death. Linnaeus practically completed Ray's classification. He used **structure as the basis** of classification. There were **six classes,** four of which were vertebrate and two invertebrate. These classes were in turn divided into **orders,** the orders into **genera,** and the genera into **species.** However, the Linnaean Genus sometimes includes three or four orders of our present arrangement of groups.

Following Linnaeus came **Georges Cuvier** (1769-1832), who in turn was followed by **De Blainville** (1777-1850). The latter's method is considered superior to that of Cuvier.

Lamarck (1744-1829) classified animals **according to their nervous sensibilities,** speaking of **apathetic** animals, that is, those without nervous systems, or apparent sensations, among the invertebrates, and the **sensitive animals,** largely also among the invertebrates, while the **intelligent** animals corresponded to the vertebrates.

Then came **Oken** (1779-1851), who suggested two different methods of classifying. Neither one, however, received much recognition. One of his systems was based upon the **arrangement of organs,** while the other was based upon the **senses.** The latter were divided into such interesting but valueless groups as **Dermatozoa** (literally, skin or touch animals), by which he meant the invertebrates; the **Glossozoa** (literally, tongue animals), the fishes; the **Rhinozoa** (nose animals), which included the reptiles; the **Otozoa** (ear animals) or the birds; and another class, which appears to have been called interchangeably the **Ophthalmozoa** (eye animals) or **Trichozoa** (hair animals), the mammals. It would be hard to name a set of distinctions less applicable as classification marks than most of these.

Pierre-Latreille (1762-1833), **Johannes Müller** (1801-1858), and **Louis Agassiz** (1807-1873), should also be mentioned among the systematists.

The **Linnaean system** has been adopted because it introduced a sharply defined grouping and a definite terminology. In other words, this system permits a grouping of forms which **resemble** each other, as well as a grouping according to **relationships other than physical resemblance.**

As already stated, Linnaeus used four general groupings: **class, order, genus** (plural, **genera**), and **species.** Modern systematists have added **phylum** (plural, **phyla**), **subphylum** (assemblies greater than the class), **class, subclass, order, suborder, family, subfamily, genus, subgenus, species, subspecies,** and sometimes others.

The following table will illustrate the present method of naming and classifying animals:

Phylum. Protozoa.
  Class. Rhizopoda.
    Order. Lobosa.
      Family. Amoebidae.
        Genus. Amoeba.
          Species. Proteus.

The botanists use a somewhat different classification, but the one here given is the one of greatest value and importance to the student. All zoölogists, although accepting this classification, do not necessarily classify the same animals under the same heading. This often leads to considerable confusion for the beginner.

The student of medicine will find that during the past twenty years a definite nomenclature has been adopted in the study of human anatomy known as the B. N. A., so called because it was brought about at an International Anatomical Conference at Basle, Switzerland, and therefore called the **Basle Nomenclatura Anatomica.**

The Linnaean system designates the species by **two Latin or Latinized names**: the **generic name**, a noun; and the **specific name**, usually **an adjective.** To this is added a third, if a subspecies is recognized. A **subspecies** is **usually** more or less **synonymous with variety in** classification, although variety is sometimes used; in fact, in one group, ants (family Formicidae), there are usually four words in the name.

The rules applying to the nomenclature, although following Linaeus are set forth in various codes. These are the **British Association Code,** the **American Ornithological Union Code,** the **Code of the German Zoölogical Society,** and the **Code of the International Zoölogical Congress.** The **International Code of Zoölogical Nomenclature**, adopted by the **International Zoölogical Congress** and governed through a Commission on Nomenclature is used almost everywhere now. Professor Schull has summed up the principal rules as follows:

"The first name proposed for a genus or species prevails on the condition that it was published and accompanied by an adequate description, definition or indication, and that the author has applied the principles of **binomial nomenclature.** This is the so-called **law of priority.** The tenth edition of the **Systema Naturae** of Linnaeus is the basis of the nomenclature. The author of a genus or species is the person who first publishes the name in connection with a definition, indication, or description, and his name in full or abbreviated is given with the name; thus, **Bascanion anthonyi** Stejneger. In citations the generic name of an animal is written with a capital letter, the specific and subspecific name without initial capital letter. The name of the author follows the specific name (or subspecific name if there is one) without intervening punctuation. If a species is transferred to a genus other than the one under which it was first described, or if the name of a genus is changed, the author's name is included in parentheses. For example, **Bascanion anthonyi** Stejneger should now be written **Coluber anthonyi** (Stejneger), the generic name of this snake having been changed. One species constitutes the **type** of the genus; that is, it is formally designated as typical of the genus. One genus constitutes the type of the subfamily (when a subfamily exists), and one genus forms the type of the family. The type is indicated by the describer, or if not indicated by him, is fixed by another author. The name of a subfamily is formed by adding the ending **inae**, and the name of a family by adding **idae** to the root of the name of the type genus. For example, Colubrinae and Colubridae are the subfamily and family of snakes of which Coluber is the type genus."

Since evolution has become more or less a keynote in the study of Biology, it has been the desire of biologists to group living structures according to a **common ancestry.** This idea has been in the minds of systematists since Darwin's time.

Similarity of species of a given genus is supposed to **indicate kinship,** so that the individuals among any given genus show greater diversity than do the members of the species going to make up that genus, although all members of the genus have something in common. We may take as an example the **vertebrates,** which constitute the so-called **highest phylum,** and the **protozoa**—the single-celled animals—which constitute the so-called **lowest phylum.** Frogs being vertebrates, that is, having a backbone, are classified in the same phylum as man, who also has a backbone, but there is much greater difference between a frog and a man than there is between the many different species of frogs.

As already stated, systematists have usually used structure for their important clue to affinities. "However," again quoting Professor Schull, "the **evidential value of similarity** in one or several structures **unaccompanied by the similarity of all parts is to be distrusted,** since animals widely separated and dissimilar in most characters may have certain other features in common. Thus, the coots ( ), phalaropes ( ), and grebes ( ), among birds have **lobate feet,** but, as indicated by other features, they are not closely related; and there are certain lizards (Amphisbaenidae), ( ), which closely resemble certain snakes (Typhlopidae), ( ), in being blind, limbless, and having a short tail. The early systematists were very liable to bring together in their classification **analogous** forms, that is, those which are functionally similar; or animals which are only superficially similar. In contrast with the early practice, the aim of **taxonomists** at the present time is to group forms according to **homology**, which is considered an indication of actual relationship. Since a genetic classification must take into consideration the entire animal, the search for affinities becomes an attempt to evaluate the results of all morphological knowledge, and it is also becoming evident that other things besides structure may throw light upon relationships. The **fossil records, geographical distribution, ecology,** and **experimental breeding** may all assist in establishing affinities."

It is, of course, necessary that, before any final classification can be made, one must know the various forms that exist and have existed in the past, and one of the greatest obstacles in this field is that most animals having a soft body have decayed and left no record of themselves among the fossil remains thus far found. Only those which possessed an intensely hard substance, or lived and died in regions where, due to the peculiar character of the soil or water, they were preserved, can furnish us with any accurate record of the past.

There are men who have taken up individual studies in order to ascertain all the details of their given specialties, and such men are named after the study-group they have adopted as such specialty; for example, one who specializes in the study of **protozoa** is called a **Protozoölogist**; one who studies **worms** is known as a **Helminthologist**; one who studies **mollusks**, a **Conchologist**; one who studies insects, an **Entomologist**, while he who studies **birds** is an **Ornithologist**, and he who studies **mammals**, a **Mammalogist.**

It is, of course, understood that these men may not be interested in classification alone, but that they may be anatomists, physiologists, ecologists, etc., also in regard to their favorite study.

The checking up of the different conclusions which different workers in the same field, and different workers in different fields, have arrived at, is one of the most interesting and valuable studies possible. This is particularly true, because so frequently all the evidence that a Paleontologist accepts, points to a totally different conclusion from that which the student of experimental genetics finds to be true. The history of science is replete with cases of groups of men having held and defended doctrines most valiantly, and with seeming correctness, entirley opposite to those of men in other fields of study.

References.

Schull, "Principles of Animal Biology."

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TABULAR VIEW OF THE CLASSIFICATION OF ANIMALS AS FAR AS ORDERS

(After Hegner, Schull, Handlirsch, Brues, Melander, Muttkowski, and Wheeler.)

PHYLUM I. PROTOZOA

Class I. Rhizopoda ( )

Order 1. Lobosa ( )
Order 2. Heliozoa ( )
Order 3. Radiolaria ( )
Order 4. Foraminifera ( )

Class II. Mastigophora ( )

Order 1. Flagellata ( )
Order 2. Choanaflagellata( )
Order 3. Dinoflagellata( )
Order 4. Cystoflagellata ( )

Class III. Sporozoa ( )

Subclass I. Telosporidia ( )
Order 1. Gregarinida ( )
Order 2. Coccidiidea ( )
Order 3. Haemosporidia ( )
Subclass II. Neosporidia ( )
Order 1. Myxosporidia ( )
Order 2. Sarcosporidia ( )

Class IV. Infusoria ( )

Subclass I. Ciliata ( )
Order 1. Holotricha ( )
Order 2. Heterotricha ( )
Order 3. Hypotricha ( )
Order 4. Peritricha ( )
Subclass II. Suctoria ( )

PHYLUM II. PORIFERA

Class I. Calcarea ( )

Order 1. Homocoela ( )
Order 2. Heterocoela ( )

Class II. Hexactinellida ( )

Class III. Demospongiae ( )

Order 1. Tetraxonida ( )
Order 2. Monaxonida ( )
Order 3. Keratosa ( )

PHYLUM III. COELENTERATA

Class I. Hydrozoa ( )
Order 1. Anthomedusae ( )
Order 2. Leptomedusae ( )
Order 3. Trachymedusae ( )
Order 4. Narcomedusae ( )
Order 5. Hydrocorallinae ( )
Order 6. Siphonophora ( )

Class II. Scyphozoa ( )

- Order 1. Stauromedusae ( )
- Order 2. Peromedusae ( )
- Order 3. Cubomedusae ( )
- Order 4. Discomedusae ( )

Class III. Anthozoa ( )

Subclass I. Alcyonaria ( )

- Order 1. Stolonifera ( )
- Order 2. Alcyonacea ( )
- Order 3. Gorgonacea ( )
- Order 4. Pennatulacea ( )

Subclass II. Zoantharia ( )

- Order 1. Edwardsiidea ( )
- Order 2. Actiniaria ( )
- Order 3. Madreporaria ( )
- Order 4. Zoanthidea ( )
- Order 5. Antipathidea ( )
- Order 6. Cerianthidea ( )

PHYLUM IV. CTENOPHORA

PHYLUM V. PLATYHELMINTHES

Class I. Turbellaria ( )

- Order 1. Rhabdocoelida ( )
- Order 2. Tricladida ( )
- Order 3. Polycladida ( )

Class II. Trematoda ( )

- Order 1. Monogenea ( )
- Order 2. Digenea ( )

Class III. Cestoda ( )

PHYLUM VI. NEMATHELMINTHES

PHYLUM VII. ECHINODERMATA

Class I. Asteroidea ( )
Class II. Ophiuroidea ( )
Class III. Echinoidea ( )
Class IV. Holothuroidea ( )
Class V. Crinoidea ( )

PHYLUM VIII. ANNELIDA

Class I. Archiannelida (**)**

Class II. Chaetopoda (**)**

Subclass I. Polychaeta ( )

Order 1. Phanerocephala ( )
Order 2. Cryptocephala ( )

Subclass II. Oligochaeta ( )

Order 1. Microdrili ( )
Order 2. Macrodrili ( )

Class III. Hirudinea (**)**

Class IV. Onycophora (**)**

PHYLUM IX. MOLLUSCA

Class I. Amphineura (**)**

Order 1. Polyplacophora ( )
Order 2. Aplacophora ( )

Class II. Gastropoda (**)**

Subclass I. Streptoneura ( )

Order 1. Aspidobranchia ( )
Order 2. Pectinibranchia ( )

Subclass II. Euthyneura ( )

Order 1. Opisthobranchia ( )
Order 2. Pulmonata ( )

Class III. Scaphopoda (**)**

Class IV. Pelecypoda (**)**

Order 1. Protobranchia ( )
Order 2. Filibranchia ( )
Order 3. Eulamellibranchia ( )
Order 4. Septibranchia ( )

Class V. Cephalopoda (**)**

Order 1. Tetrabranchia ( )
Order 2. Dibranchia ( )

PHYLUM X. ARTHROPODA

Class I. Crustacea ( )

Subclass 1. Branchiopoda ( )
Subclass 2. Ostracoda ( )
Subclass 3. Copepoda ( )
Subclass 4. Cirripedia ( )
Subclass 5. Leptostraca ( )
Subclass 6. Malacostraca ( )

Class II. Merostomata ( )

Order 1. Gigantostraca ( )

Class III. Poecilopoda ( )

Order 1. Xiphosura ( )

Class IV. Linguatulida ( )

Order 1. Pentastomoidea ( )

Class V. Pantopoda ( )

Order 1. Clossendromorpha ( )
Order 2. Nymphomorpha ( )
Order 3. Pycnogomorpha ( )

Class VI. Arachnoidea ( )

Subclass 1. Cteiphora ( )

Order 1. Scorpiones ( )

Subclass 2. Lipoctena ( )

Order 1. Pedipalpi ( )
Order 2. Araneae ( )
Order 3. Meridogastres ( )
Order 4. Opiliones ( )
Order 5. Acarina ( )
Order 6. Cheloneti ( )
Order 7. Solifugae ( )

Class VII. Myriapoda ( )

Subclass 1. Opisthogoneata ( )

Order 1. Chilopoda ( )

Subclass 2. Progoneata ( )

Order 1. Symphyla ( )
Order 2. Pauropoda ( )
Order 3. Diplopoda ( )

Class VIII. Mirientomata (   )

Order 1. Protura (   )

Class IX. Collembola (   )

Order 1. Arthropleona (   )
Order 2. Symphopleona (   )

Class X. Campodeoidea (   )

Order 1. Rhabdura (   )
Order 2. Dicellura (   )

Class XI. Thysanura (   )

Order 1. Lepismatoidea (   )
Order 2. Machiloidea (   )

Class XII. Pterygogenea
(Insecta sensu stricto), (   )

Subclass 1. Orthopteroidea (   )

Order 1. Grylloblattoidea (   )
Order 2. Orthoptera (   )
Order 3. Phasmoidea (   )
Order 4. Diploglossata (   )
Order 5. Dermaptera (   )
Order 6. Thysanoptera (   )

Subclass 2. Blattaeformia (   )

Order 7. Mantoidea (   )
Order 8. Blattoidea (   )
Order 9. Zoraptera (   )
Order 10. Isoptera (   )
Order 11. Corrodentia (   )
Order 12. Mallophaga (   )
Order 13. Siphunculata (   )

Subclass 3. Hymenoptera (   )

Order 14. Hymenoptera (   )

Subclass 4. Coleopteroidea (   )

Order 15. Coleoptera (   )
Order 16. Strepsiptera (   )

Subclass 5. Embidaria (   )

Order 17. Embiidina (   )

Subclass 6. Libelluloidea ( )

Order 18. Odonata ( )

Subclass 7. Ephemeroidea ( )

Order 19. Plectoptera ( )

Subclass 8. Perloidea ( )

Order 20. Plecoptera ( )

Subclass 9. Neuropteroidea ( )

Order 21. Megaloptera ( )
Order 22. Raphidoidea ( )
Order 23. Neuroptera ( )

Subclass 10. Panorpoidea ( )

Order 24. Panorpatae ( )
Order 25. Trichoptera ( )
Order 26. Lepidoptera ( )
Order 27. Diptera ( )
Order 28. Suctoria ( )

Subclass 11. Rhynchota ( )

Order 29. Homoptera ( )
Order 30. Hemiptera ( )

GROUPS OF INVERTEBRATES OF MORE OR LESS UNCERTAIN SYSTEMATIC POSITION

Group 1. Mesozoa ( )
Group 2. Nemertinea ( )
Group 3. Nematomorpha ( )
Group 4. Acanthocephala ( )
Group 5. Chaetognatha ( )
Group 6. Rotifera ( )
Group 7. Bryozoa ( )
Group 8. Phoronidea ( )
Group 9. Brachiopoda ( )
Group 10. Gephyrea ( )

PHYLUM XI. CHORDATA

Subphylum I. Cephalochorda or
Adelochorda ( )

Subphylum II. Urochordata or Tunicata ( )

Order 1. Larvacea ( )
Order 2. Ascidiacea ( )
Order 3. Thaliacea ( )

Subphylum III. Hemichordata ( )

Order 1. Enteropneusta ( )
Order 2. Pterobranchiata ( )
Order 3. Phoronidia ( )

Subphylum IV. Vertebrata or Craniata ( )

Class I. Cyclostomata ( )

Subclass 1. Myxinoidea ( )
Subclass 2. Petromyzontia ( )

Class II. Pisces or Gnathostomata ( )

Subclass 1. Elasmobranchii ( )

Order 1. Plagiostomi ( )

Suborder I. Selachii ( )
Suborder II. Batoidei ( )

Order 2. Holocephali ( )

Subclass II. Teleostomi ( )

Order 1. Crossopterygii ( )
Order 2. Chondrostei ( )
Order 3. Holostei ( )
Order 4. Teleostei ( )

Subclass III. Dipneusti (Dipnoi), ( )

Class III. Amphibia ( )

Subclass I. Stegocephali ( )

Subclass II. Lissamphibia ( )

Order 1. Apoda (Gymnophiona), ( )
Order 2. Urodela ( )
Order 3. Anura ( )

Class IV. Reptilia ( )

Order 1. Chelonia ( )
Order 2. Crocodilia ( )
Order 3. Sauria (Squamata), ( )
Division I. Lacertilia ( )
Division II. Ophidia ( )

Class V. Aves ( )

Subclass I. Archaeornithes ( )

Subclass II. Neornithes ( )

Order 1. Hesperornithiformes ( )
Order 2. Ichthyornithiformes ( )
Order 3. Struthioniformes ( )
Order 4. Rheiformes ( )
Order 5. Casuariiformes ( )
Order 6. Crypturiformes ( )
Order 7. Dinornithiformes ( )
Order 8. Aepyornithiformes ( )
Order 9. Apterygiformes ( )
Order 10. Sphenisciformes ( )
Order 11. Colymbiformes ( )
Order 12. Procellariiformes ( )
Order 13. Ciconiiformes ( )
Order 14. Anseriformes ( )
Order 15. Falconiformes ( )
Order 16. Galliformes ( )
Order 17. Gruiformes ( )
Order 18. Charadriiformes ( )
Order 19. Cuculiformes ( )
Order 20. Coraciiformes ( )
Order 21. Passeriformes ( )

Class VI. Mammalia ( )

Subclass I. Prototheria ( )

Order 1. Monotremata ( )

Subclass II. Eutheria ( )

Division I. Didelphia ( )

Order 1. Marsupialia ( )

Division II. Monodelphia ( )

Section A. Unguiculata ( )

Order 1. Insectivora ( )
Order 2. Dermoptera ( )
Order 3. Chiroptera ( )
Order 4. Carnivora ( )
Order 5. Rodentia ( )
Order 6. Edentata ( )
Order 7. Pholidota ( )
Order 8. Tubulidentata ( )

Section B. Primates ( )

Order 9. Primates ( )

Section C. Ungulata ( )

Order 10. Artiodactyla ( )
Order 11. Perissodactyla ( )
Order 12. Proboscidea ( )
Order 13. Sirenia ( )
Order 14. Hyracoidea ( )

Section D. Cetacea ( )

Order 15. Odontoceti ( )
Order 16. Mystacoceti ( )

BRIEF CHARACTERIZATIONS OF THE MAJOR GROUPS OF ANIMALS

The principal groups of animals are given below with brief diagnoses which may serve as definitions. It must be understood that the characters given will often not be sufficient to distinguish all the forms in a group, for there is much variation within the groups. They are intended to give the student a general conception of the phyla, subphyla and classes.

Phylum PROTOZOA ( ). Single celled animals without true organs or true tissues. If colonial, the cells are all potentially alike.

Class RHIZOPODA ( ). Protozoa with changeable protoplasmic processes (pseudopodia). Amoeba.

Class MASTIGOPHORA ( ). Protozoa with one or more vibratile processes (flagella) which serve for locomotion and for taking food. Euglena.

Class SPOROZOA ( ). Parasitic protozoa, usually without motile organs or mouth, reproducing by spores. Malarial parasite.

Class INFUSORIA ( ). Protozoa having numerous slender vibratile processes (cilia), a cuticle, and fixed openings for the ingestion of food and the extrusion of indigestible matter. Paramoecium.

Phylum PORIFERA ( ). Diploblastic, radially symmetrical animals with body wall penetrated by numerous pores. Body usually supported by a skeleton of spicules or spongin. Sponges.

Class CALCAREA ( ). Sponges with spicules composed of calcium carbonate, monaxon, or tetraxon in form.

Class HEXACTINELLIDA ( ). Sponges with spicules composed of silicon, triaxon in form.

Class DEMOSPONGIAE ( ). Sponges with spicules composed of silicon, not triaxon in form, or skeleton composed of spongin, or with skeleton of both spicules and spongin.

Phylum COELENTERATA ( ). Diploblastic, radially symmetrical animals with tentacles, stinging cells, single gastrovascular cavity, no anus. Two body forms are prevalent, the hydroid and the medusa. Jellyfishes, polyps and corals.

Class HYDROZOA ( ). Coelenterates without stomodaeum and mesenteries; sexual cells discharged to the exterior; hydroid and medusa forms in the life history of same species, or only the medusa, the latter having a velum. Polyps (including Hydra), a few corals, small jellyfishes.

Class SCYPHOZOA ( ). Coelenterates with only the medusoid, not hydroid form; velum lacking; notches at margin of umbrella. Larger jellyfishes.

Class ANTHOZOA ( ). Coelenterates without medusoid forms, with well developed stomodaeum and mesenteries. Sea anemones, most corals.

Phylum CTENOPHORA ( ). Triploblastic animals; symmetry partly radial, partly bilateral; eight rows of vibratile plates radially arranged. Sea walnuts or comb jellies.

Phylum PLATYHELMINTHES ( ). Triploblastic, bilaterally symmetrical animals with body flattened, with a single gastrovascular cavity (sometimes wanting) and no anus. Flatworms.

Class TURBELLARIA ( ). Free-living flatworms with ciliated epidermis. Planaria.

Class TREMATODA ( ). Parasitic flatworms without cilia but with a hardened ectoderm, usually parasitic and with attaching suckers. Flukes.

Class CESTODA ( ). Parasitic flatworms with the body differentiated into a head (scolex) and a chain of similar joints (proglottides), the whole being usually regarded as a colony. Tapeworms.

Phylum NEMATHELMINTHES ( ). Bilaterally symmetrical, triploblastic animals with an elongated cylindrical body covered with a cuticle, with a true body cavity, and a digestive tract with both mouth and anus. Roundworms.

Phylum ECHINODERMATA ( ). Radially symmetrical (with minor exceptions), triploblastic animals with well developed coelom, and usually with five antimeres, spiny skeleton of calcareous plates, and organs of locomotion known as "tube feet" operated by a water-vascular system. Starfishes, sea urchins, sea cucumbers.

Class ASTEROIDEA ( ). Free-living, typically pentamerous echinoderms with wide arms not sharply marked off from disc and with ambulacral grooves. Starfishes.

Class OPHIUROIDEA ( ). Free-living, typically pentamerous echinoderms with slender arms sharply marked off from disc and no ambulacral grooves. Brittle stars.

Class ECHINOIDEA ( ). Free-living, pentamerous echinoderms without arms; the outer covering composed of calcareous plates bearing movable spines. Sea urchins, sand dollars.

Class HOLOTHURIOIDEA ( ). Free-living, elongated, soft-bodied echinoderms with muscular body wall and tentacles around mouth. Sea cucumbers.

Class CRINOIDEA ( ). Sessile echinoderms with five arms generally branched with pinnules, aboral pole usually with cirri, sometimes with jointed stalk for attachment to substratum. Feather stars, sea lilies.

Phylum ANNELIDA ( ). Triploblastic, bilaterally symmetrical elongated animals with external and internal segmentation; coelom usually present; setae common. True worms.

Class ARCHIANNELIDA ( ). Marine annelida with no setae nor parapodia. Polygordius and Protodrilus.

Class CHAETOPODA ( ). Annelida with setae and a perivisceral coelom; marine, fresh-water, or terrestrial in habitat. Earthworms.

Class HIRUDINEA ( ). Annelida without setae, and with anterior and posterior suckers. Leeches.

Class ONYCOPHORA ( ). Annelida breathing by means of tracheal tufts, numbering from 10 to 40 per segment in irregular arrangement, with non-jointed papillate legs, nerve cords ventro-lateral, and without segmental ganglia, eyes of vesicular, annelid type, skin with chitin. This group is often placed with the arthropoda, or as a separate phylum proarthropoda, since its members have developed somewhat in the arthropodan direction. Lankester thinks their evolution is as follows:

Group Articulata

1. Rotifera to Tardigrada
2. Chaetopoda
    a. Proarthropoda (Peripatus) developing independently.
    b. Crustacea—separate origin from Chaetopoda.

From Crustacea by separate origin

a. Myriapoda
b. Insecta
c. Arachnida.

Paleontologists, such as Walcott, the specialist on trilobites and worms, derive all arthropoda classes by separate lines from trilobites.

Phylum MOLLUSCA ( ). Triploblastic, bilaterally symmetrical (symmetry often obscured) unsegmented animals with a coelom, a muscular foot and usually a shell. Mollusks.

Class AMPHINEURA ( ). Mollusks with obvious bilateral symmetry, sometimes an eight-parted calcareous shell and several pairs of gills. Chitones and Chaetoderma.

Class GASTROPODA ( ). Mollusks with a head and with bilateral symmetry usually obscured by a spiral shell of one piece. Snails.

Class SCAPHOPODA ( ). Mollusks with conical tubular shell and mantle. Dentalium.

Class PELECYPODA ( ). Mollusks without a head, with bilateral symmetry, a shell of two lateral valves and a mantle of two lobes. Clams, mussels.

Class CEPHOLOPODA ( ). Mollusks with distinct bilateral symmetry and a foot bearing eyes and divided into arms, usually with suckers. Cuttlefishes, octopods.

Phylum ARTHROPODA ( ). Triploblastic, bilaterally symmetrical, segmented animals with usually more or less dissimilar somites, a coelom very much reduced, paired jointed appendages, and chitinous exoskeleton.

Class CRUSTACEA ( ). Arthropods breathing by means of gills, two pairs of antennae, crayfishes, crabs, shrimps. Certain terrestrial species with tracheae (Oniscidae—sowbugs).

Class MEROSTOMATA ( ). Fossil arthropoda of gigantic size (2 meters in length), without antennae, short cephalothorax, 12 segments in abdomen, and pointed telson. Eurypterus.

Class POECILOPODA ( ). Arthropoda with large shield-shaped cephalothorax, abdomen with six pair lamellate legs, with extremely long pointed telson. Limulus, king crabs.

Class LINGUATULIDA ( ). Parasitic arthropoda (Pentastomidae) of worm-like build, body with metameric circular muscles, two pairs of hooks in region of mouth, mouth without mandibles. Affinities uncertain.

Class PANTOPODA ( ). Marine arthropoda, body segmented, abdomen vestigial, with not more than seven pairs of legs, mouth a beak. Ammothea Pycnogonoides.

Class ARACHNOIDEA ( ). Arthropods with either tracheae, book lungs or book gills, or both, and no antennae. Harvest-men, spiders, mites, ticks, scorpions.

Class MYRIAPODA ( ). Arthropods with distinct head, one pair antennae, breathing through tracheae, whose stigmata are placed in linear metameric arrangement, many legs. Myriapods and millipeds, centipeds.

Class MIRIENTOMATA ( ). Minute microscopic arthropoda (600-1600 micra), with six legs, a three-segmented thorax (?), no antennae, post-embryonic increase of segments, first pair of legs transformed into sense organ. These minute forms were only recently discovered, and their affinity is uncertain.

Class COLLEMBOLA ( ). Arthropods with six-segmented abdomen, no post-embryonic increase in segments, one-jointed tarsi, few tracheae, these opening in one pair of stigmata at the throat, abdomen generally with spring. Snow-fleas, springtails.

Class CAMPODEOIDEA ( ). Arthropods with long body, abdomen ten segments, with cerci. No eyes, mouth-parts withdrawn, no post-embryonic change in abdominal segments. Sprintails.

Class THYSANURA ( ). Arthropods with free mouth-parts and palpi, three caudal appendages, abdomen eleven segments and covered with silvery scales, frequently with spring beneath. Silver fish, fish moths.

Class PTERYGOGENEA ( ). Insecta, hexopoda. Winged arthropods, with three pairs of legs, embryos with twelve segments to abdomen, adults with all degrees of post-embryonic reduction from twelve to six segments. Breathe through tracheae; stigmata linear and metameric in arrangements. **True insects—i. e., winged arthropods.**

Phylum CHORDATA ( ). Animals having at some time during their life's history a notochord lying between the nervous system and the alimentary tract, a hollow central nervous system lying entirely on one side of the digestive canal, and pharyngeal slits extending from the pharynx to the exterior.

Subphylum CEPHALOCHORDA or **ADELOCHORDA** ( ). Fish-like chordates with a permanent notochord composed of vacuolated cells, such as **amphioxus.**

Subphylum UROCHORDATA or **TUNICATA** (   ). Sac-like marine animals with a cuticular covering known as a tunic or test. This group possesses a notochord only in the caudal region. Example, **tunicates.**

Subphylum HEMICHORDATA (   ). Worm-like chordates of doubtful systematic position. There is a projection from the mid-dorsal region of the alimentary canal similar to a notochord. These animals possess a collar and a proboscis. Example, **balanoglossus.**

Subphylum CRANIATA or **VERTEBRATA** (   ). Chordates in which the notochord either persists or becomes invested with cartilage. Vertebrates have a segmented spinal column.

Class CYCLOSTOMATA (   ). Eel-like vertebrates without functional jaws or lateral appendages. Examples, hagfishes and lampreys.

Class PISCES or **GNATHOSTOMATA** (   ). Fishes with a lower jaw and paired pectoral and pelvic fins, scales and paired nostrils. The heart has an auricle, a ventricle, a conus arteriosus, and a sinus venosus.

Class AMPHIBIA (   ). Cold-blood vertebrates breathing by means of gills at some stage of their life-cycle. Skin not usually covered with scales. Three chambers in heart beside the conus arteriosus and sinus venosus. Frogs, toads, newts, and salamanders.

Class REPTILIA (   ). Cold-blooded vertebrates breathing by means of lungs throughout their life-cycle. Usually covered with scales. Lizards, snakes, crocodilians, and turtles.

Class AVES (   ). Warm-blooded vertebrates, whose body is usually covered with feathers and the fore-limbs modified for wings. Heart of four chambers. Birds.

Class MAMMALIA (   ). Warm-blooded animals with hair covering at some stage in their life-cycle. They suckle their young and have a diaphragm between thorax and abdomen.

Subclass PROTOTHERIA (   ). Egg-laying mammals. Example, monotremes, such as the Australian duck-bill.

Subclass EUTHERIA (   ). Mammals which give birth to living young. These are the true mammals.

Division DIDELPHIA or **METATHERIA** (   ). These are the marsupials, such as the opossum and kangaroo.

Division MONODELPHIA (   ). These are the placental animals which are nourished in the body of the mother through a true placenta.

INVERTEBRATE GROUPS OF UNCERTAIN POSITION

Certain groups of invertebrates have not been assigned a definite relation to other groups. Opinion differs so widely as to their affinities that they may well be kept out of our regular classification for the present.

Mesozoa. Parasites apparently intermediate between the Protozoa and Metazoa. Not improbably degenerate relatives of the flatworms.

Nemertinea. Terrestrial, fresh water, and marine animals resembling flatworms but with a proboscis, blood vascular system, and alimentary canal with two openings.

Nematomorpha. Long thread-like animals with the body cavity lined with epithelium, a pharyngeal nerve ring and a single ventral nerve cord.

Acanthocephala. Parasitic worms with spiny proboscis, a complex reproductive system and no alimentary canal.

Chaetognatha. Marine invertebrates with a distinct coelom, alimentary canal, nervous system and two eyes.

Rotifera. Invertebrates with a head provided with cilia, usually a cylindrical or conical body often with a shell-like covering and a bifurcated tail or foot provided with a cement gland.

Bryozoa. Mostly colonial invertebrates resembling hydroids in form, with distinct coelom, and with digestive tract bent in the form of a letter U.

Phoronidea. A single genus of worm-like animals having tentacles and living in membranous tubes in the sand.

Brachiopoda. Marine tentacles animals with a calcareous shell, composed of two unequal shell-parts (commonly called valves), a dorsal and a ventral.

Gephyrea. Worm-like animals of doubtful affinities.

PRONOUNCING - INDEX - GLOSSARY

TABLE OF PREFIXES AND SUFFIXES

(To be Memorized)

The object of this Index-Glossary is not to furnish a detailed explanation. This must be sought in the text on the page assigned. The object is to give the student such knowledge of the technical words used in Biology as will enable him to take apart the words he finds in his scientific reading and analyze them. Therefore, he must learn all of the immediately following prefixes and suffixes:

A or an (G. prefix, without) e.g. apoda, i.e. without feet.

Ab (L. prefix, away from) e.g. aboral i.e. away from the mouth.

Ad (L. prefix, toward, upon) e.g. adrenal i.e. upon the renal gland.

ae plural-ending for Latin sigular nouns ending in A.

Ambi (L. prefix, both) e.g. ambidextrous, i.e. ability to use both hands.

Amphi (G. prefix, on both sides) e.g. amphibia, i.e. to live on land and in water.

Ante (L. prefix, before in place or time) e.g. antebrachium, i.e. placed before the arm.

Anti (G. prefix, opposite, or opposed to) e.g. antitoxin, i.e. opposing or neutralizing a toxin.

Arch (G. prefix, chief or early) e.g. archenteron, i.e. the earliest enteron or digestive tract.

Auto (G. prefix, self) e.g. auto-intoxication, i.e. poisoning produced within one's own body.

Bi (L. prefix, double) e.g. bilateral, i.e. same on both sides.

Blast (G. either prefix or suffix, a sprout, or bud), e.g. blastoderm, and neuroblast, i.e. a primitive germ-layer and a primitive nerve cell.

Brevis (L. short) e.g. adductor brevis, i.e. the short adductor.

Caudad (L. tail) used only in an adverbial sense, as growing caudad, i.e. tailword, or toward the tail.

Cephalad (G. head) used only in an adverbial sense, as growing toward the head.

Chondro (G. gristle or cartilage) e.g. chondrocranium, i.e. that part of the cranium developing from cartilage.

Circum (L. prefix, round-about) e.g. circumoesophageal, i.e. running around the oesophagus.

Cleido (L. clavicle—key) e.g. sterno-cleido mastoid muscle, i.e. the muscle attached to the sternum, clavicle and mastoid bones.

De (L. prefix, off) e.g. degenerate, i.e. to become inferior — to lose generative ability.

Di (G. prefix, twice) e.g. diploblastic, i.e. to remain in the two-germ-layer state.

Dorsad (L. back) used only in an adverbial sense, as toward the back.

Ecto (G. prefix, outside) e.g. ectoderm, i.e. the germ-layer lying toward the outside.

En (G. prefix, within), e.g. encephalon, i.e. brain—within the cephalon or head.

Endo (G. prefix, within), e.g. endoderm, i.e. the germ-layer lying toward the inside.

Ento—Same as Endo.

Epi (G. prefix, upon) e.g. epinephros, i.e. same as adrenal, namely, lying upon the nephridic organ.

Ex (G. prefix, without or outside) e.g. exoskeleton, i.e. having a skeleton on the outside.

form (L. suffix, shape) e.g. fusiform, i.e. shaped like a spindle.

Genetic (G. to produce) e.g. pathogenetic, i.e. to produce disease.

Hemi (G. prefix, half) e.g. hemisphere, i.e. half a sphere.

Hyper (G. prefix, above or beyond) e.g. hypertrophy, i.e. an overgrowth.

Hypo (G. prefix, under) e.g. hypoglossal, i.e. under the tongue.

Infra (L. prefix, below) e.g. infraorbital, i.e. beneath the orbit.

Inter (L. prefix, between) e.g. intercellular, i.e. between the cells.

Intra (L. prefix, within) e.g. intracellular, i.e. within the cell.

Laterad (L. side), used only in an adverbial sense, as "toward a side."

lysin (G. suffix, a loosing or dissolving) e.g. bacteriolysin, i.e. a substance which dissolves bacteria.

Macro (G. prefix, large) e.g. macrocephalon, i.e. a large head.

Major (L. greater) e.g. pectoralis major, i.e. the greater of the pectoral muscles.

Mega (G. great) e.g. megaspore, i.e. the larger of the spores.

Mesiad (G. middle), used only in an adverbial sense, as "to grow mesiad" or toward the center of the body.

Meso (G. prefix, middle) e.g. mesoderm, i.e. the middle germ-layer.

Meta (G. prefix, after) e.g. metaphase, i.e. the phase in mitosis coming after the prophases.

Micro (G. prefix small) e.g. micro-organisms, i.e. organisms not seen by the naked eye.

Minor (L. lesser) e.g. pectoralis minor muscle, i.e. the lesser pectoral muscle.

Mono (G. prefix, alone) e.g. monogamy, i.e. marrying but one spouse.

Multi (L. prefix, many) e.g. multicolored, i.e. many-colored.

Myxo (G. prefix, slime) e.g. myxophyceae, i.e. slime-algae.

oid (G. suffix), to be added to make an adjective, e.g. odontoid, i.e. like a tooth.

Para (G. prefix, beside) e.g. parachordal, i.e. lying beside the notochord.

Peri (G. prefix, around) e.g. pericardium, i.e. around the heart.

Poly (G. prefix, many) e.g. polymorphic, i.e. many-formed.

Post (L. prefix, after) e.g. postbranchial, i.e. behind the gills.

Pre (L. prefix, before) e.g. pre-oral, i.e. before the mouth.

Pro (G. prefix, first, or early) e.g. probranchia, i.e. the first gills that form.

Pseudo (G. prefix, false) e.g. pseudopods, i.e. false feet.

Retro (L. prefix, backward) e.g. retrolingual, i.e. backward from the tongue.

Semi (L. prefix, half) e.g. semicircular, i.e. half circle.

Sub (L. prefix, under) e.g. submandibular, i.e. under the mandible.

Supra (L. prefix, above) e.g. supratemporal, i.e. above the temporal bone.

Sur (same as supra) e.g. surangulare, i.e. above the angulare bone.

Tera (G. prefix, monster)e.g. teratology, i.e. the study of monstrosities.

Tetra (G. prefix, four) e.g. tetrapoda, i.e. four-footed animals.

Toxic (G. poison) e.g. toxemia, i.e. toxic + haemia, blood-poison.

Uni (L. prefix, one) e.g. uniramous, i.e. single branch.

Ventrad (L. belly) used only as an adverb of direction, as "to grow ventrad."

INDEX-GLOSSARY*

In all probability some of the pronunciations, as well as some of the derivations, will not meet with the approval of those who are specialists in Latin and Greek, for, often various forms of words have been used to show the student the varying forms of the same word that he will meet in scientific literature, rather than the same form throughout. Thus, for example, **meros,** thigh, and **meros,** a segment, have both been translated as though they were spelled alike. In Greek, the former has a long "e" and the latter a short "e", which really makes the words totally different.

Then, too, in pronunciation, those who have learned and know a foreign language will always (and rightfully so) pronounce the word as it is pronounced in that language. This makes any definite pronunciation impossible, at least to the exclusion of other pronunciations.

Englishmen learn an Anglicised Latin pronunciation, while Continental Europeans and Americans pronounce their "a" as in lark, "e" as the "a" in lake, and "i" as the "e" in see.

Dictionaries have sometimes used one method and sometimes another. The European is likely to pronounce "c" in such words as **cephalon** as "k", though in America this is not customary, but is sometimes heard.

Not each and every artery, vein, and nerve has been listed separately, as these appear under the more general headings of "Circulatory System" and "Nervous System," but one of a name has been listed so as to show the manner of usage of the definative word. The same word is often used in different senses. The references cited have been chosen to make these different meanings clear.

If the page number is in italics, the word indexed is to be looked for **under the illustration on** the page assigned.

Lastly, as this book is written solely for the student, we have used everything which would make matters clearer to him. Therefore, although generally using a consistent marking for the pronunciation, we have also brought in a type of marking which he will find in some of the books, and it is well that he be familiar with it. Such is the case, for instance, in **tiu'ni kay'tah,** for **tū'ni kā'tâ,** as it is generally given.

KEY TO PRONUNCIATION.

ā—as in fate.	ĕ—as in hen.	ō—as in go.	ow—as in cow.
ă—as in fat.	ê—as in her.	ŏ—as in not.	ū—as in pure.
â—as in far.	ī—as in pine.	ô—as in form.	ŭ—as in nut.
ē—as in he.	ĭ—as in pin.	oi—as in toy.	û—as in French u.

KEY TO DERIVATIONS.

Ar.—Arabian.	G.—Greek.	L. L.—Late Latin.	O. F.—Old French.
A. S. Anglo-Saxon.	Hind.—Hindustani.	M. D.—Middle Dutch.	O. H. G.—Old High German.
F.—French.	Icel.—Icelandic.	M. E.—Middle English.	P.—Portuguese.
Gael.—Gaelic.	It.—Italian.	M. L.—Middle Latin.	Sp.—Spanish.
Ger.—German.	L.—Latin.	N. L.—New Latin.	Sw.—Swedish.

* As there is considerable variation in usage when foreign words are pronounced, such pronunciation has been chosen as seemed consistent with the best usage of the language from which the word was taken, as well as from international usage. Consequently, many words are as yet not authoritatively defined as to pronunciation and exact derivation.

It is hoped these may be added in a future edition of this book. The author will, therefore, consider it a favor to receive any and all suggestions which may be of help.

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