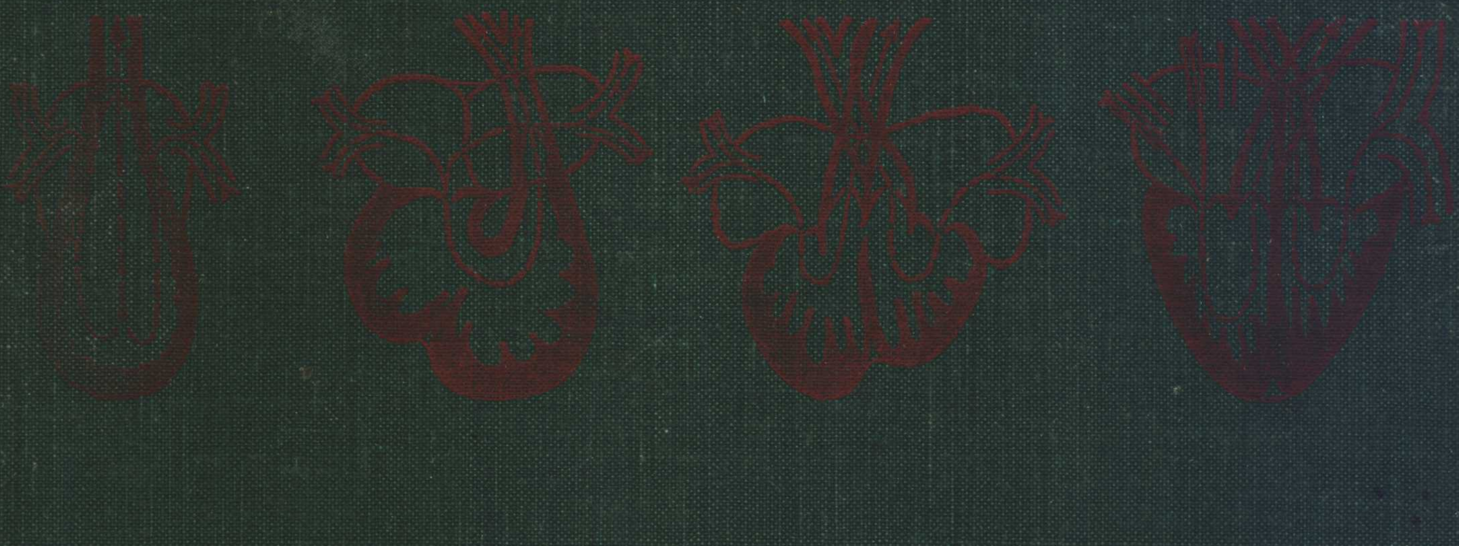
J. E. WODSEDALEK



GENERAL ZOOLOGY

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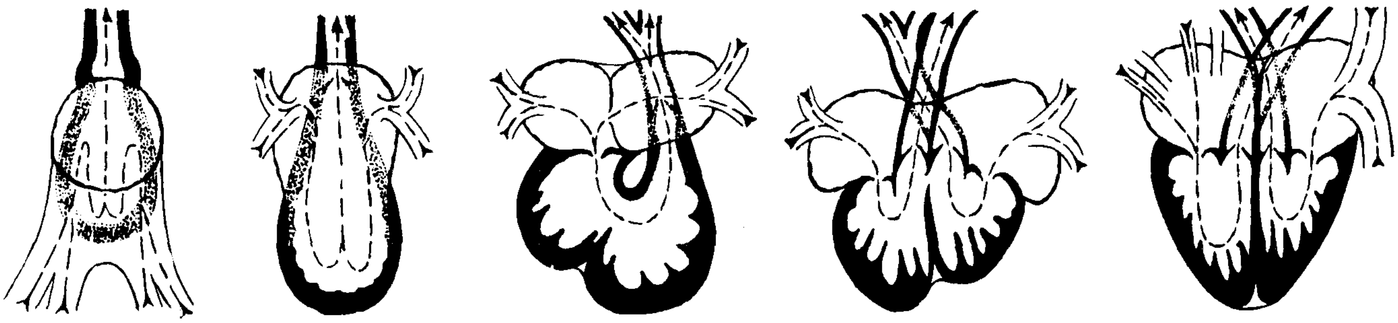

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Preface

There are a number of textbooks that contain material intended for use in the introductory course in college zoology. However, there is need for one that coordinates the textual material with the important laboratory work – one that supplements the laboratory studies and in which the supplementary and reference context is presented in the same orderly manner and can be readily found and referred to by the student. Students become discouraged and their interest in a fascinating subject wanes when they cannot locate the material or are obliged to spend, unnecessarily, altogether too much time searching for it in the discursive type of book arrangement. Many college faculty members have voiced the same criticism.

This book was written in response to the numerous requests from college and university zoologists using the author's illustrative method of general zoology laboratory guidance, administrators and others, including thousands of students. They have felt the need for a textbook closely correlated with the laboratory exercises. The book is the result of over forty years of experience in active teaching of general zoology and other courses on university level – lecturing, directing and supervising large laboratory sections, pursuing extensive research in evaluating various methods of instruction and the relative values of various forms of examinations, training teachers, counseling, etc. Organizing a course in human biology in a large university and conducting large university classes in the subject for many years should be emphasized here, since the experience and knowledge thus gained have aided the author in including, in a comparative way, wherever feasible and desirable, the many phases of human biology. As a student and throughout my university career I was quite cognizant of the fact that students in college zoology were more interested in the human organism than they were in lower animals. This is only natural for man is the most important member of the animal kingdom and accordingly his structure, from cells to organs, systems, physiology, genetics, and other biological aspects are not neglected in this treatise.

Many photomicrographs of human cells, tissues, and organs, as well as many full-page anatomical drawings of human systems are included for comparative study. For example, in laboratory not all students are greatly interested in the dissection and study of the fetal pig as such, but they are interested in mammalian anatomy and physiology and their interest and endeavors are promptly enhanced with the realization that much of what they learn about the lowly mammal is, by way of comparison, applicable to mankind. Similarly the purpose of the laboratory study of the skeleton and muscles of the frog becomes clarified with the splendid opportunity offered for comparative study of the corresponding bones and muscles of man. All through the book, beginning with cells, tissues, organs, systems, and continuing with physiology, genetics, etc., the human element is interpolated, partly to maintain interest but more specifically for a broader knowledge of zoology and a better understanding of man and his position in the world of life. However, care is taken here not to overemphasize human biology to the negelct of other animal types. At the same time with proper organization and selection of material and skillful presentation both can be included without overstuffing the context.

For about ten years it has been the author's good fortune to travel much of the time each year thus covering practically every section of the country. The object of the travels was to visit as many universities, colleges, and junior colleges as carefully planned itineraries permitted. These trips afforded every opportunity to study, rather privately, the general educational policies of the schools and more particularly the status of the zoology or biology departments especially in relation to the General Zoology and General Biology courses.

I was interested not only in the methods of laboratory procedure of these courses, because of my **laboratory guides in zoology and biology** but in their over-all scope – the lectures, outside reading and study, the textbooks used, their objectives, examinations, and standards of achievement. I was interested in the attitudes of the faculties, and equally as much, if not more so, in the opinions of students who had taken the courses or were taking them at the time. Whether the department had adopted the author's widely-used illustrative method of laboratory guidance based on sound, thoroughly tested, educational techniques or some other method, efforts were made to contact many individuals and to obtain their unbiased opinion as to the type of laboratory procedure they prefer. The question of textbooks used and the purpose they were intended to serve also received attentive consideration. Students and faculty alike were quite ready and explicit in expressing their wishes and wants in regard to a general zoology textbook and obviously had given the matter considerable thought before I contacted them. Everywhere the students' reaction was the same – North, East, South, and West – in the coastal, inland, metropolitan, and suburban areas. A strong desire for a text skillfully and pedagogically coordinated with the laboratory material was generally apparent. This is in harmony with the teaching philosophy long entertained by the author.

The modern college course in general zoology is quite different from that of two or three decades ago. The great field of zoology is growing rapidly and new highly successful methods of presentation, especially in laboratory instruction, have been developed. In a considerable majority of the institutions, large and small, the introductory courses in zoology are of high quality. It was gratifying to find so many smaller colleges offering work in general zoology that compares most favorably with that of the big-name universities. Indeed, on occasion, I was amazed at the very high caliber of work in some relatively small four-year colleges, state teachers colleges, and junior colleges.

This author most emphatically regards General Zoology, the first course in the department, as of great fundamental importance – the hallmark of real scholarship – especially in this age of greater emphasis on science. A well organized and well taught course should provide not only the necessary foundation and prerequisite for advanced courses and specialties of any department, it should furnish a broad background for the various professions such as medicine, dentistry, nursing, medical technology, dental hygiene, pharmacy, agriculture, veterinary medicine, forestry, dietetics, public health, game management, and many others. It is to the credit of the faculties in many colleges and universities that general zoology is suggested as an elective to fulfill the laboratory science requirement in such fields as general arts, journalism, education, commerce, and public relations.

Furthermore, for the vast majority of students who take no further work in the department, an up-to-date general zoology course provides a liberal education in itself for it embodies cultural as well as practical values. It should furnish an opportunity for the student to develop his capacity to think clearly; to rationalize matters;

in brief, to be better able to cope with life's problems and social conditions. It should help him build a sound philosophy of life and enrich his mental sphere. In moments of leisure and deliberation there is intellectual satisfaction that comes to those who are well informed biologically. Contemplation of marriage in itself requires zoological knowledge as an aid to marital success and happiness.

Since we have numerous detailed drawings for guidance in the laboratory directions, it seemed desirable to have photographic and microphotographic illustrations of much of the material in the textbook. This obviates duplication of the author's many original drawings which are provided in the guide. Furthermore, good photographs represent more accurate images of what the student actually sees under the microscope; what he is supposed to study and what we would like to have him master and remember. Photographs, like well executed drawings, free from distortion, form valuable devices for instruction and are indubitably superior to lengthy verbal discussions. No effort, time, or expense was spared to provide the best possible illustrations for the benefit of the instructor as well as the student. Over one thousand drawings, photographs, photomicrographs, and electromicrographs shown in this book are new and have not been published before. Relatively few photographs of animal types have been borrowed from other sources. Proper acknowledgments accompany such photos and are not tucked away in some remote part of the book. In this book all illustrations not accompanied by the usual courtesy acknowledgments are solely the property of the author.

For many months the author was fortunate to have the services of Dr. August Ruthmann who was completing the requirements for his doctorate degree in the Zoology Department of the University of Minnesota, with a major in cytology under Dr. Joseph G. Gall, my successor. The author spent much time in the preparation of material and in searching through his extensive collection of slides and depicting favorable cells, tissue areas, sections of embryos, anatomical structures, and so forth, but most of the actual beautiful photographic work was accomplished through the skill of Dr. Ruthmann, who is also an expert in electron microscopy and the scrupulous technique it requires. The several unusual electronmicrographs shown in this book were made by him in connection with his research in cytology and cellular physiology. These and many others were generously presented to me with his compliments. The advantages of having the services of a broadly trained scientist for this type of work, coupled with several years of experience in teaching General Zoology and other courses in a university, are obvious.

Just as excellent photographs serve a useful purpose in teaching and studying most phases of biology, accurate drawings are practically indispensable. One of the cogent factors contributing to the remarkable success of the author's *General Zoology Laboratory Guide* is the liberal use of his many, new, original, painstakingly made drawings. In coordinating this text with my laboratory guide, the production of illustrations followed the same orderly method of precision and it is hoped that this will represent an equally significant contribution to facilitate teaching of the many aspects of college zoology. Here, again, nothing was spared in the production of the many new and helpful illustrations. Heretofore, the author made his own drawings. For this publication an experienced biological and medical illustrator was employed for some of the work in order to save time and for purposes of continued accuracy and excellence.

The author devoted considerable time over a period of more than two years to numerous conferences with Carl Petterson, biological and medical illustrator, in planning the details of the many drawings so they would conform to the author's proven educational concepts and ideals, and thus help to dovetail the text with the authentic laboratory material into an orderly, coherent, authoritative and workable whole. All cytological drawings were made by the author.

In the production of the drawings every endeavor was made to adhere to the author's unswerving commitment to the standard of excellence. Most zoologists regard poor figures as detrimental rather than helpful because the student is apt to retain an image of the crude, deficient and inadequate illustrations and thereby take with him many erroneous impressions. The illustrations in some books are frequently oversimplified, too diagrammatical, ill-proportioned or out of proper perspective.

A certain amount of classification is necessary in the general zoology course. However, there is a common practice of devoting too much space to this phase, the greater part of which is of little use to the student in the beginning course. I am including here the extent of classification which a survey of many general zoology instructors indicates is quite ample — the more important phyla, their classes, and in the case of insects and mammals the more important orders. In general the scientific name of the species is given in the case of all organisms studied in the laboratory and those of special interest or of economic importance, such as the various parasites, etc. As a distinct departure from the usual approach to classification of simply giving the technical terms and examples under the various divisions, I am using early in many chapters discreetly planned and specially made illustrations intended to make an indelible impression in depicting the distinguishing characteristics of the groups of organisms that represent the various phyla and, as a rule, also the different classes. In the case of the class **Mammalia** the orders are similarly treated. It is hoped that this innovation of using rather striking plates will serve a manifold purpose as they vividly portray the relationship and classification of the various animal types, linked with their usual common names, and in general shown in their natural habitat. The phylogenetic arrangement is deliberate and purposeful.

During many years of university teaching this author conducted a teachers' course in the biological sciences intended, primarily, for prospective high school and junior college teachers. This afforded an acquaintance with the requirements of the high school biology courses as prescribed in many states. Since many of the students entering college had the advantage of a good course in high school biology an effort has been made here, wherever pedagogically desirable, to avoid the use of elementary or repetitious material and to complement the students' previously acquired knowledge with subject matter on the college level. The quality of the course should be a challenge to the scholastic capacities of the college student and the quantity of work should be consistent with the time made available for it by the institution's authorities. Understandably, it would be unwise to encroach on the realms of the more advanced courses in special fields of zoology.

The scientific attitude has been maintained throughout. Parts of the subject matter that is often arduous to the student have been kept at a minimum of what is essential for the proper interpretation of the principle involved. Biological principles are emphasized and an effort has been made to avoid lengthy discussions and vague generalizations. In general the physiological aspects of the many representative types of animals and man are emphasized but presented in a way that does not make the subject burdensome to the student who does not have an extensive foundation in physics and chemistry.

I am indebted to Dr. August Ruthmann, my photographer, for the production of the numerous, entirely new, excellent photographs, photomicrographs, and electronmicrographs, and to Drs. Gall and Syverton for the excellent photomicrograph of human chromosomes. I want to thank Carl Petterson, my artist, who made many of the drawings, as we planned them, to conform with my proven educational concepts and ideals. In this connection I also want to thank Dr. A. S. Romer for giving us permission to pattern, after his illustrations, many of the fossil forms represented as silhouettes in our Fig. 42.10. I wish to express my appreciation to Dr. W. J. Breckenridge, Director of the Museum of Natural History, University of Minnesota, for granting us the privilege to photograph numerous exhibits. Many of the groups were constructed by Dr. Breckenridge, others by C. E. Brandler and Jenness Richardson, while the background was painted by C. A. Corwin and R. Bruce Horsfall. Grateful acknowledgment is also made to Marilynn Friend, my secretary, for typing the entire manuscript, preparing the index, and assisting in reading proof. I feel deeply indebted to the many zoologists who are using my method of laboratory instruction and who have urged the production of this supplementary coordinated textbook. It is their proficient administration of the method that accounts for its success. Just as my original *General Zoology Laboratory Guide* introduced an entirely new approach to biological laboratory studies which after 25 years is still leading the field in laboratory workbooks, so should this entirely new *General Zoology Textbook*, with the new underlying theme of the cell and cellular physiology, set the pattern for future textbooks in the field of biology.

Finally, it is a pleasure to express my appreciation of the very cordial cooperation and continued encouragement I have received from my publishers, the Wm. C. Brown Company.

J. E. WODSEDALEK

January, 1963

Contents

1 Introduction

The current educational trend is toward greater emphasis on the field of **science.** What is science? The term is derived from the Latin word *scientia* which means knowledge. The word is so comprehensive that it is difficult to formulate a brief and inclusive definition. For our purpose we may define science as organized knowledge which can be verified. Science deals with facts or realities as they are determined by the human intellect and the generalization of those facts.

The generalization of facts may be a **theory** or a tentative statement advanced to explain facts as observed and interpreted, or it may be a **law** which, in science, is a correct statement of the invariable occurrence of some natural phenomenon in the same way under specific conditions. It is an established or a proven principle such as the law of gravitation. Theories and laws are formulated primarily by the method of induction, or reasoning from specific facts to the generalization. The opposite method of approach is referred to as deduction, or the deductive method of reasoning, from the generalization to the specific facts.

When we speak of social sciences we refer to sociology, history, and so on. The natural sciences are the **physical sciences** such as chemistry, physics, and astronomy, and the **biological sciences** as zoology, botany, and bacteriology. There is no sharp demarcation between the two general classes of natural science. As our knowledge of the numerous phases of the two increases the gap between them becomes narrower. The two fields are interdependent and there is a growing realization of the need of cooperation between them.

Zoology (Gr. *zoön,* animal + *logos,* discourse) is a science dealing with the study of animals, and that includes man. The science dealing with the study of plants is **botany** (Gr. *botane,* plant). The study of all life, both plant and animal, is **biology** (Gr. *bios,* life, + *logos,* discourse).

Life. What is life? We ourselves are alive and see life manifested in innumerable forms around us. In most instances we can readily distinguish living objects from the nonliving, but the phenomenon of life is not easily defined. Of the many attempts to define life probably the most widely known is that stated by the eminent biologist and philosopher of the nineteenth century, Herbert Spencer, who said – "Life is the continuous adjustment of internal relations to external relations." However, that still does not tell us what life really is. In spite of all of our modern knowledge of the living substance and the many manifestations of life the phenomenon defies human explanation and probably always will. The nature and activities of living matter will be beautifully illustrated in your laboratory study of living amoeba, one of the simplest forms of animal life, and the student's understanding of the many wondrous life processes will gradually become enriched as he diligently pursues his studies in this course.

Scope of Zoology. Zoology is an exceedingly broad field of science and covers many subdivisions or special areas. Like other sciences it has its own vocabulary and the new terms should be mastered as the student comes to them. This is not difficult if their derivations are known. The derivations are usually indicated when the new term is encountered the first time, or they may be found in the dictionary. Most of the zoological terms come from Greek (Gr.) or Latin (L.) terminology. The suffix **"logy"** is used frequently and has its origin in the Greek term *logos* which means study or discourse. It should not be necessary to repeat its meaning in each case. Some of the subdivisions are enumerated and briefly defined here:

Morphology (Gr. *morphe,* form + *logos,* discourse), study of the general form and structure of animals.

Anatomy (Gr. *ana,* up + *temno,* cut), structure of the body as made out by dissection.

Histology (Gr. *histos,* tissue), microscopic structure of tissues and organs.

Cytology (Gr. *kytos,* hollow place, cell), detailed study of the structure of, and function within cells.

Embryology (Gr. *embryon,* embryo), early developmental stages of animals.

Physiology (Gr. *physis,* nature), functions of organisms or parts of them.

Taxonomy (Gr. *taxis,* arrangement + *nomos,* law), laws and principles of classification.

Ecology (Gr. *oikos,* house), relation of animals to their environment.

Genetics (Gr. *genesis,* origin), science of heredity.

Eugenics (Gr. *eu,* well + *genes,* born), being well born.

Evolution (L. *e,* out + *volvo,* roll), development of the race or species from ancestral forms.

Ontogeny (Gr. *ontos,* something existing + *genesis,* origin), life history of the individual from the fertilized egg to maturity.

Phylogeny (Gr. *phylon,* race + *genesis,* origin), history of the development of the race or species.

Paleontology (Gr. *palaios,* ancient + *ont,* being) fossil organisms.

Pathology (Gr. *pathos,* suffering) symptoms, nature, and causes of disease.

Psychology (Gr. *psyche,* mind), mental life.

Space Biology, of life problems of manned space missions.

An understanding of all of the foregoing terms is not absolutely necessary at the outset but the meaning of the terms should be learned when subject matter pertaining to some particular branch is undertaken. For example, it is not necessary to learn the definition of **ontogeny** and **phylogeny** until the **Biogenetic Law** is explained and discussed and the terms become more meaningful. Otherwise it would be only a matter of memorizing a definition without knowing what it is all about. That is not knowledge.

To give the student a further general view of the scope of zoology a few other zoological sciences may be mentioned. For example, protozoology is the science of protozoa; parasitology, of parasites; entomology, of insects; helminthology, of parasitic worms; conchology, of the shells of mollusks; ichthyology, of fish; herpetology, of amphibians and reptiles; ornithology, of birds, oölogy, of birds' eggs; mammalogy, of mammals; zoogeography, of geographical distribution of animals; immunology, of immunity to disease; hematology, of blood; endocrinology, of endocrine glands and their secretions; sociology, of animal societies; etc.

Zoological Principles. For over two thousand years many zoologists have devoted the greater portion of their lives to study and experimentation in one or the other of the many branches of this fascinating and important science. Through their scholarly endeavors important scientific principles, theories, and laws relative to life – the most important thing on our planet – have been formulated and directly or indirectly are of inestimable practical, intellectual, and cultural values to mankind – the most important organism on this earth.

The Method of Science. In the course of civilization many problems have been solved and more new ones continue to arise. In solving scientific problems scientists employ a method that is widely known as the **scientific method.** It involves several steps: (1) Formulating of hypotheses or ideas relative to the problem on the basis of what little is known about it. (2) Testing the correctness of the hypothesis by accurate first-hand observation or carefully planned experimentation. (3) Compiling an orderly record of the facts observed, which must be verifiable. (4) Drawing conclusions on the basis of clear thinking and reasoning, which may result in the propounding of a theory. (5) If the facts of the theory are repeatedly verified and the principle is accepted by a vast majority of those who know most about the particular subject, the theory can be accepted as proved and declared a law. Of course, there remains the familiar adage – "absolute proof is never attained."

In the light of new knowledge the interpretations of many theories have, from time to time, been modified or enlarged upon. However, to the author's knowledge no biological law has ever been abandoned. The same is probably true of other natural sciences, which only goes to show how accurate and thorough the scientists are in their work and how cautious in their pronouncements. If a flaw should be detected in a proposed theory, the scientists and not those of other fields of endeavor will discover it for they are their own severest but unbiased critics. It will be well for the student to bear that in mind. That is the scientific method.

Aims of General Zoology. As the word "general" implies, the objectives of this course are broad and general in design. There is no intent to specialize in any particular branch of zoology. The aim is to impart to the student a wide fundamental knowledge of animal biology; to give him a good acquaintance with the animal kingdom – from amoeba up the scale including man; to help him understand human biology and man's place in nature, in relation to other organisms; to furnish a large body of facts fundamental to the proper interpretation of the important principles of zoology; to make him conscious of important biological problems; to acquaint him with social, economic, and kindred problems, the solution of which is dependent on biological knowledge; to stress the value of zoological information in relation to the many phases of agriculture, fisheries, forestry, conservation, nutrition, sanitation, health, and disease; to demonstrate the scientific method; to inculcate respect for scientific authority; to lay a sound foundation for advanced study, research, and the various professions; to help the student develop reverence for the whole subject of sex, procreation, etc. – in brief, to aid him in building a good philosophy of life, and a way to better and more useful citizenship. Manifestations of zoological training may well be the earmarks of college graduates.

Brief Historical Background of Zoology. To bring the history of zoology into the proper perspective for the student it may be useful to divide it into a number of periods.

1. **The Greek World.** Although early Greek scholars and philosophers made some studies in the various phases of science, including zoology, they relied mainly on emotions, hearsay, and superstition. We will, therefore, begin with the contributions of Aristotle (384-322 B.C.) as the originator of zoology. He overshadowed his predecessors because in his studies of natural history, zoology, comparative anatomy, embryology, and physiology he depended on his own observations, used the inductive method of reasoning, and thus introduced the scientific method.

2. **The Roman World.** The influence of Aristotle spread to Rome where in the first century A.D. Pliny made extensive compilations of the results of the work of others and became known as the uncritical compiler. In the second century A.D. the most outstanding Roman scientist was Galen (130-200). He was a great anatomist and physician who studied by means of dissection. Being forbidden the use of human bodies for dissection, he had to rely on the dissection of goats and apes. He also experimented with living animals. His books remained authoritative in medical schools for twelve hundred years.

3. **The Middle Ages.** This period (about 500-1400), also known as the **Dark Ages** because of intellectual inferiority, saw no material progress in zoology. The attempts were of mythological nature as illustrated by the bestiaries, or treatises describing characteristics, mostly fanciful, of animals. The period extended for over one thousand years.

4. **The Renaissance Period.** In the sixteenth century Andreas Vesalius (1514-1564), a great Belgian anatomist, broke away from the "authority" of Galen and in 1543 published an extensive treatise entitled "On the Structure of the Human Body," based on detailed dissections and careful observations. The publication was beautifully illustrated by the famous artist Calcar, a student of Titian (real name, Tiziano Vecellio).

5. **The Seventeenth Century.** William Harvey (1578-1657), an English physician, was the first to demonstrate by experiments that the blood circulates through the body, being forced out of the heart, going to various parts of the body and returning back to the heart again. In 1628 he published his epoch-making monograph – "On the Motion of the Heart and Blood in Animals." The publication had a profound influence on zoology, particularly in the field of general physiology.

Robert Hooke (1635-1703), an English scientist, was the first to use the term cell. His publication "Micrographia" appeared in 1665. More detail about his work is given in the chapter on the cell. Anton van Leeuwenhoek (1632-1723), a Dutch microscopist, discovered **PROTOZOA**, bacteria, and rotifers, and over a period of years reported his results to the Royal Society of London.

6. **The Eighteenth Century.** The name that stands out in the eighteenth century is that of Carolus Linnaeus (Sw. Karl von Linnē, 1707-1778), a Swedish scientist noted for his work in taxonomy, who gave us the binomial system of nomenclature. His greatest work, "Systema Naturae," published in 1735 passed through twelve editions of which the tenth (1758) has been accepted as the basis for zoological nomenclature and is still in use.

7. **The Nineteenth Century.** The **Cell Theory,** one of our most important biological generalizations, that all living organisms are composed of cells, came into sharp focus during the first part of the nineteenth century. Contributions to this principle were made by many biologists, notably by Mirbel (1802-1809), Dutrochet (1824), Brown (1831), Meyen (1828-1838), Purkinje (1835), Mohl (1835), and others, all of whom in view of historical information should be given credit for their due share in developing this doctrine. Many textbooks erroneously continue to misplace the credit to Schleiden and Schwann, both of whom made contributions in their respective fields but were entirely wrong in their interpretation of important matters pertaining to cells and cell division.

Charles Darwin (1809-1882), an Englishman, after more than twenty years of collecting, organizing, and interpreting zoological material, in 1859 published a book entitled "The Origin of Species by

Means of Natural Selection" which probably exerted a greater influence on zoology than any other single scientific publication.

Louis Pasteur (1822-1895), a French chemist, is best known for proving (1861) that bacteria and other microörganisms do not develop spontaneously in nutrient material. By heating cultures to destroy all organisms and then sealing them to prevent re-invasion he demonstrated the principle of sterilization which was promptly introduced in medicine and surgery, in preserving food by canning, pasteurizing milk, etc. The principle of sterilization has been extended to the use of chemicals in safeguarding water supplies and in many other aspects of sanitation.

Gregor Johann Mendel (1822-1884), an Austrian monk, probably of Czech and German ancestry, a contemporary of Pasteur, discovered the fundamental laws of heredity and published his results in 1866 and very clearly stated the laws of heredity known today as the Mendelian laws of inheritance. The laws are equally applicable to plants and animals, including mankind. The very important results of his experiments escaped notice of his contemporaries, including Darwin, for thirty-five years but were rediscovered in 1900 by Correns of Germany, De Vries of Holland and Tschermak of Austria, all working independently. Bateson of England and Castle of America should also be mentioned here for their independent work followed closely that of the three others named.

The last quarter of the nineteenth century saw strides in the field of cytology, particularly in work on the nature and behavior of chromosomes, and is known as the "classic period of cytology."

8. **The Twentieth Century.** The opening of this century (1900) is marked by the rediscovery of Mendelism by the men just mentioned. In 1901 Hugo De Vries, a famous Dutch botanist and one of the rediscoverers of Mendel's work, published "Die Mutationtheorie." The publication was based on his twenty years of experimentation and study carried on with evening primroses (*Oenothera lamarckiana*) and gave us the Mutation Theory of evolution. Mutations are sudden heritable variations and are distinguished from acquired somatic modifications which are not heritable. Today there is a tendency in America to limit the meaning of the word mutation to a single gene mutation as distinct from other hereditary changes, such as chromosome changes.

Thomas Hunt Morgan (1866-1946), an American zoologist and geneticist who made many contributions to experimental embryology, is best known for his work in genetics. His classical experiments on the fruit fly *Drosophila melanogaster* started in 1910 and continued on a very extensive scale for thirty-five years, first at Columbia University and later at the California Institute of Technology at Pasadena. He published over two hundred technical papers and was the author of several books. As one of the most prominent geneticists he made outstanding contributions to the mechanism of heredity and in 1933 was the recipient of the Nobel prize.

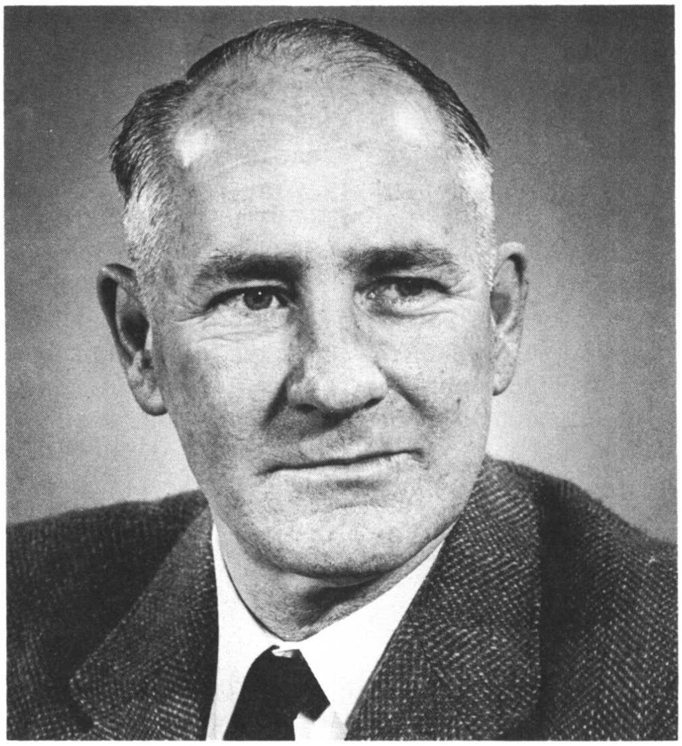

Fig. 1.1. George Wells Beadle (1903–), a Nobel Prize winning American.

Today genetics holds a high place in the entire field of modern biology. It is intimately associated with cytology. The solution of basic problems of both cytology and genetics lies within the realms of biochemistry and biophysics. Biochemistry, cytology, genetics, and biophysics constitute a strong force which is responsible for our rapidly growing knowledge of the architecture of proteins and nucleic acids in relation to heredity. A prominent leader in the application of the chemical method to the study of mutations is Dr. George Wells Beadle (1903 –) (Fig. 1.1), formerly Director of the Division of Biology at the California Institute of Technology and now Chancellor of the University of Chicago. Dr. Beadle received the Nobel Prize in Medicine in 1958 for his research in genetics on the manner in which genes control enzymes and enzymes control the basic chemistry of the cell.

2

Protoplasm

Physicochemical Basis of Life

Historical

One of the greatest scientific events was the discovery that the phenomena of life are associated with a fluidlike substance now called protoplasm. Although earlier workers made scattered observations on the living material in plants and animals, Dujardin, a Frenchman, the most famous early pioneer in the study of protoplasm, was the first to describe it in 1835 and is generally given credit for its discovery. He studied it in **PROTOZOA** and other lower animals and named it sarcode (Gr. *sarx,* flesh). In some of his writings he stressed the significance of the formation of vacuoles in living matter, a capacity not attributable to inanimate proteins.

Purkinje, a Czech biologist, studied the living substance in plant and animal material, especially in embryos, and in 1839 was the first to use the term **protoplasm.** Following the researches of Max Schultze (1861), the concept of protoplasm as the universal material of both plants and animals came into general use. In his classic essay, Thomas Huxley (1868) referred to protoplasm as "the physical basis of life." The chemical, physical, and physiological aspects of this colorless, viscous material, in general, are fundamentally the same in living organisms everywhere. However, the fact remains that every species of plant and animal, indeed, every individual has its modified kind of protoplasm. This is evidenced in such physiological states as are involved in many phases of metabolism, susceptibility to disease, allergy, and immunity.

Chemical Composition of Protoplasm

The same elements that occur in nonliving matter also occur in protoplasm. However, of the ninety-odd elements that are known to exist in matter, the living substance is composed almost entirely of only twelve. The four most common elements present in the human body are Oxygen 65%; Carbon 18%; Hydrogen 10%; Nitrogen 3%, making a total of 96% of the body by weight. In addition there are small but necessary amounts of Calcium, Phosphorus, Potassium, Sulphur, Sodium, Chlorine, Magnesium, and Iron — listed in the order of their abundance. There are minute traces of several more such as cobalt, zinc and iodine, which will be mentioned from time to time in some special cases.

It can be seen from the foregoing that there is no element or group of elements found exclusively in protoplasm to which its vital characteristics may be attributed. However, Carbon is very essential, for it is fundamentally involved in the physicochemical organization of protoplasm. It is intermediate in its properties between bases and acids. It has four bonds or valences and may enter into chemical combination with almost any other element. It also combines with itself as it forms rings characteristic of carbohydrates, and chains characteristic of fats. The complexity of the protein molecule is possible because of the properties of the element carbon.

Elements, or atoms, as they are commonly known, are usually combined with other elements to form molecules of **compounds;** using the familiar examples, 2 atoms of hydrogen combine with 1 atom of oxygen to form one molecule of water; and 1 atom of carbon combines with 2 atoms of oxygen to form one molecule of carbon dioxide. Atoms, and molecules, are usually indicated by symbols. Letter H. stands for an atom of hydrogen, O of oxygen, C for carbon, N for nitrogen, etc. The molecular formula for compounds is also indicated by symbols. Since a molecule of water is composed of 2 atoms of hydrogen and 1 of oxygen the formula for water is written as H_2O; similarly the formula for carbon dioxide is CO_2. Although there are less than 100 different kinds of atoms known, it is obvious that by means of various combinations of the different elements a large number of different kinds of molecules can be produced. Similarly the large numbers of different kinds of pure molecules may be mixed together in various combinations so that an enormous number of different kinds of material can be produced.