GENERAL BIOLOGY

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PREFACE

As in previous editions, the emphasis in this text is on the organism. I believe that living things should not be forgotten amid the explanations of the processes and principles that enable them to survive. The attitude of a colleague, "Why should I care what species it is? The first thing I do is to grind it up," may appear reasonable to a biochemist, but it is only part of the story for a biologist.

In the preface to the tenth edition, I related the comments of a young secretary who was an English major. She said, "Red-haired men, spinach cells, and cats! I can understand this text!" Recently, one of the professors using the text wrote that "my students can understand its presentation and they like it." I hope that the students and their instructors who use the present edition will share these attitudes.

Users of former editions will find much that is familiar in the present text. Although minor changes have been made in almost every chapter, the major change in this edition is in the sequence of topics. I hope that the reorganization will make the text more convenient for both student and instructor.

The text now contains six parts. Part one, Introductory biology, consists of 12 chapters containing most of the material considered in the first term of a yearlong sequence. The first two chapters introduce science, biology, scientific procedure, and general characteristics of life. Chapter 3 introduces nutrients and a small amount of chemistry. This is a modification of former Chapter 7 and part of the basic chemistry formerly in the appendix. Cell biology, reproduction, and growth and development in various organisms is considered in Chapters 4 through 7. The material on genetics has been moved to Chapters 8 and 9. The whole organism emphasis of the text is now reestablished in Chapters 10 through 12, which emphasize the kinds of living things, ecology, behavior, and relationships among organisms.

Part two, Microbiology, includes viruses, monera, simple algae, protozoa, and fungi. Part three, Plant biology, and Part four, Animal biology, continue the discussion of the structural, functional, and evolutionary relationships among the variety of living forms. The phylum-by-phylum approach has been retained. Part five, The biology of man, includes chapters on the human form, human metabolism, human control mechanisms, and human reproduction. Evolution is discussed in Part six.

The glossary includes basic terms, prefixes, suffixes, and combining forms used in biology. The appendix contains material on the early history and development of biology.

I am grateful to those users of former editions who suggested changes of one kind or another. I also wish to express my thanks to Dr. Charles Chantell, who made suggestions and improvements to the chapter on the chordates.

George B. Noland

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THE SCIENCE OF BIOLOGY

Before beginning the formal study of biology, it might be well to consider who is reading this text. Two groups of students can be readily recognized. The first and most obvious is composed of those who want to study biology as a preparation for their life's work. These are biology majors and medical technology, predental, and premedical students. Also included are increasing numbers of psychology, sociology, engineering, and philosophy students. Biology also serves as a foundation for professions such as pharmacy, nursing, agriculture, forestry, entomology, horticulture, and landscape gardening. Preparation for these professions involves the interrelationship of many sciences: chemistry, biology, physics, geology, and others.

However, most students in the introductory classes are not biology majors. Moreover, many are taking a biology course only to fulfill a science requirement. And many choose biology simply to avoid chemistry, physics, or some other science. These students' interests are not in science, but in the world of ideas and service. Very likely, the best expression of their attitudes is that they do not openly object either to biology or to science in general.

This attitude is not new or even unusual. Some years ago the English author C.P. Snow called attention to it in his book, *Two Cultures and the Scientific Revolution*. He thought that there was a widening gap between those whose beliefs and attitudes are shaped by facts and experiments and those persons of a more humanistic and subjective inclination. C.P. Snow, and many others, saw a growing danger that these two groups would no longer be able to communicate with each other.

WHY STUDY BIOLOGY?

At the risk of seeming overly dramatic, the answer to this question may well be "in order to survive!" Many people believe that the field of biology may be able to bridge the gap discussed in Snow's book.

If we consider some of the problems confronting people in the United States, as well as in many other countries, we will find that they are concerned with various aspects of biology. Newspaper and television reports emphasize that air and water pollution, inadequate nutrition, expanding population, pesticide poisoning, and destruction of natural resources are now part of our daily lives. (See box below.)

Our concern with issues such as pollution, pesticides, PCB's, and toxic hazards is a good example of the importance of biology in our lives. The extra cost of new cars because of emission controls is another example. When we talk about food shortages, miner's lung, cancer and carcinogens, water and air pollution, minerals and nutrition, and the possible side effects of medicines, we are acknowledging our absolute need to consider the basic biologic factors influencing the quality of life.

Legal and moral aspects of test tube babies, abortion, and heart, kidney, and lung transplants continue to plague the average person as well as the Congress, the courts, and the churches. We are at the point now where individual legislators are actually forced to vote on the question of when a life begins and when it ends.

A long and involved court case delayed the construction of a TVA dam on the Middle Tennessee River. It was thought that a small fish, called a snail

SHELLFISH-ASSOCIATED GASTROENTERITIS—NEW HAVEN, CONNECTICUT*

An outbreak of gastroenteritis occurred on November 16, 1968, following a shellfish sanitation association meeting in New Haven; 17 persons became ill after a cocktail party where mixed drinks, raw oysters and hard clams, potato chips, cheese snacks, and a hot sauce were served. The illness was characterized by nausea, vomiting, fever, and diarrhea with 16 of the 17 persons having diarrhea. Of 12 families surveyed with index cases, five reported secondary cases with these same symptoms. One other case occurred in the man who delivered the clams to the party and who consumed a dozen of them on November 13. He became ill 32 hours later on November 14.

Food histories from 23 persons at the party showed that 19 ate clams and 20 ate oysters. The one person who ate only clams became ill while the two persons who ate only oysters did not become ill. Of all food items, only the clams were found to be significantly associated with illness.

The clams were part of 11½ bushels of cherrystones and little necks harvested by a shellfish dealer on November 12 from a bed 3 miles southwest of Norwalk, Connecticut. One bushel was used at the party and the other 10½ were sent to a retail market in Yonkers, New York. On November 22, investigation showed that the clam bed was contaminated and, as a result, was closed to further harvesting. From December 2 through 6, samples taken twice a day from the bed also revealed abnormal contamination. In late October, waters near the bed had been of acceptable quality. The Yonkers health department was notified, but no increase in gastroenteritis cases were noted in Yonkers in November.

The probable source for the contamination was a sewage treatment plant located in eastern Norwalk that discharges the plant effluent 4.4 miles upstream from the bed. On November 11, the plant had no electricity for 4½ hours. Consequently, because the storage capacity of the system is 2 hours, there was a major overflow of the storage system for at least 2½ hours.† During the power failure, attempts were made to chlorinate the major overflow points with hypochlorite powder.

Because of the possibility of hepatitis developing following the ingestion of contaminated raw shellfish, most of the persons at the party received immune serum globulin and were observed for 2 to 6 weeks. Frozen stool specimens for virus isolation and rectal swabs for bacterial culture were also solicited, and additional clams were harvested from the contaminated beds for virus studies.

*From Morbidity and mortality weekly report, United States Public Health Service, Feb. 8, 1969.

†The possibility of a similar problem exists whenever there is a power failure anywhere in the country. Since this report, raw sewage has been dumped in San Francisco, Miami, Cleveland, and other cities. (See also p. 235.)

darter, occurred in a 12-mile stretch of the river and nowhere else. The fish was thought to be an endangered species and construction was halted. Arguments on this case are still going on.

Recent laboratory experiments have demonstrated that it is possible to take the DNA of one species and combine it with that of another. The combination enables the second species to produce something that it was unable to produce with its own genetic makeup. This recombinant DNA research may have tremendous benefits in agriculture and medicine.

Some of the problems that surround this issue include questions of commercial ownership and whether research in this area should be federally licensed and controlled for safety reasons. The United States Supreme Court ruled in 1980 that bacteria that have been genetically altered can be patented. Since then a number of patents have been granted and more are pending. What this will do to the traditional openness of research results is a question for the future.

It should be obvious by now that many of the apparently biologically based problems are also moral, ethical, economic, and political problems. There is a good possibility that these same problems, or others similar to them, are being studied in many different departments of one's school. Table 1-1 shows some examples of biologic research.

TABLE 1-1 Biology-related problems in other fields

DEPARTMENT	EXAMPLE OF BIOLOGICALLY ORIENTED RESEARCH
History	Effect of epidemics on ancient civilizations
Political science	Regulation of water and air pollution
Psychology	Biochemical control of mental illness
Sociology	Population control and society
Philosophy	Biomedical ethics
Theology	Morality of organ transplants; abortion, genetic "engineering"
Anthropology	Blood groups and genes in native groups
Engineering	Artificial organs, bioengineering
Physics	Physical properties of complex macromolecules
Chemistry	Biochemistry of pesticides

The failure to appreciate and understand the true nature of science has caused much misunderstanding and criticism of the value of its methods. Scientists can use only the tools that are available to them—they can investigate the chemical and physical processes inherent in living things and attempt to explain life in terms of such investigations. The most powerful tool used by all scientists is the scientific method. There may be variations in the steps to be followed when using the scientific method, but the following steps are representative.

SCIENTIFIC METHOD

A course in biology or any other science should give the student an idea of the aim and nature of science, the methods employed, and its value and limitations. *Science* attempts to observe and describe facts and to relate them to each other; its conclusions are always subject to revision in the light of newly discovered facts.

There are numerous popular concepts concerning what science either tries to do or can do. Some people think that science can do anything and can solve all problems. Others are fearful or apprehensive of science.

Scientific credibility suffers when individual scientists differ on the *uses* of scientific data concerning environmental quality, food, population, causes of cancer, arrest and cure of cancer, care of the aged, health care, energy availability and use, and other concerns. This is especially apparent when we are given conflicting reports from agencies such as the Food and Drug Administration and various manufacturers. Often, the apparent conflict is caused by the release of incomplete data by a news source; in many cases a ruling must be made even if all of the data are not yet available.

Steps in the scientific method

1. Recognition of the problem

Previously unnoticed problems or conditions occur constantly in our work and in our daily lives. These problems may be simple or extremely complex, requiring sophisticated techniques and experiments for their solution. The recognition of a specific problem may be stimulated (1) by mere general curiosity, (2) by an actual need for the solution of the problem, or (3) by reading or thinking about a similar problem.

Indeed, several famous discoveries are reputed to have been stimulated by such things as being hit by a falling apple, by daydreaming while watching bubbles rise in a glass, and by a nightmare after a late evening. Most, however, are the result of hard work. The study that follows this section was based on an old legend about red-haired people.

In the solution of any problem a main objective should be to ascertain the truth. In part, at least, this depends on an attitude in which problems are approached with an open, unprejudiced mind and with as much objectivity and detachment as possible.

2. Accurate preliminary observation

This includes studying available information to determine what is already known about the condition being investigated. It also includes conducting preliminary investigations and gathering information from other sources. This step is naturally not exhaustive in its scope but merely lays the foundation for the next step.

3. Formulation of a hypothesis

A hypothesis might be considered a guess, speculation, or assumption that is a tentative explanation of the problem. It is sometimes called a working hypothesis because we work from it. Sometimes only one hypothesis for a given problem can be suggested, whereas for another many hypotheses are evident. Each is considered in turn, those that are not proved are eliminated, and possibly new ones are substituted as progress is made.

4. Testing the hypothesis

Another important phase is the decision on methods of investigation. In some problems devising the proper methods of investigation may require broad practical training, imagination, special techniques, or even elaborate equipment or apparatus. In all cases the data and information must be sufficiently extensive to reduce the chance effects of unusual differences or variations.

A hypothesis may be tested (1) through additional observations and investigations, (2) through controlled scientific experiments, if such can be performed in the particular problem, or (3) by a combination of these.

It is essential to use a control group of organisms under conditions identical to the conditions of the experimental group, except that the one condition being examined is not applied to the control group. All factors, except the one we are attempting to discover, are duplicated carefully in the controls. Only one variable should be permitted between the experimental and control groups at any one time.

5. Evaluation of the collected data

As relevant data and information are collected, they must be precisely recorded. All measurements, records, interpretations of data, or "case histories" must be accurate and sufficiently comprehensive to be reliable. The investigator must be honest and faithful, his or her observations must be accurate, and records must contain all data relevant to the problem. Sometimes graphs, tables, and summaries are valuable in this step of the technique.

6. Drawing conclusions

After the information and data are recorded in such ways as to give accurate and meaningful revelations, they must be interpreted correctly. This means checking the hypothesis. Great care must be taken not to draw conclusions that are broader than the collected facts will support.

7. Repeatability and reporting the results

We have all heard the lament of the professor, "publish or perish." The "publish" part of this statement is an absolute insistence that the results of experiments be made available to the scientific community. This is done by presenting papers and discussions before groups of workers in the same field. Here, the results may be questioned, observations may be made on the techniques used, and interpretations may be made. The report may then be published in a scholarly journal, such as *Science, Genetics, American Journal of Botany, Experimental Cell Research,* or any of several thousand more.

Other workers may attempt to repeat the experiment in their laboratories. If repeatable in these different settings, the results have been verified. The data become part of biologic literature and are available to others interested in the same topics. The investigation discussed in the following section was published in an English journal, *The Practitioner*.

Much of the material in Chapter 9, Genes and Gene Action, is basically a treatise on the use of the scientific method.

An example of the scientific method

The following comments refer to similarly numbered sections of the article, "Blood coagulation and platelet function in red-haired men," on the next pages. Refer to it before continuing with this section.

1 The study of science proceeds as an outcome of a natural curiosity and a human need to know. In the red-haired study the question to be answered was "Do red-haired subjects bleed more easily than non–red-haired subjects?"

2 The first procedure was to answer still another question, "What does 'red-haired' mean?" In determining this, a study was made of the methods used by other workers. As can be seen, several methods for distinguishing red hair had been in use. Both the method and a reference to the procedure were given. One procedure, apparently the most accurate, was chosen. A second group of subjects, none of whom had red hair, was selected as a control. This second group served as a standard of comparison for the results of testing the red-haired group. The question was now rephrased as, "Does the blood of the experimental group (red hair) clot more slowly than the blood of the control group (non–red hair)?"

3 The details of the procedure were then given. The researchers were saying, "This is how we ran the test to determine if our subjects were really red-haired. This is what we mean when we say 'red-haired.' "

Next, by referring to the library, they determined the kinds of tests that are used to determine the clotting properties of human blood. The tests were listed and a reference concerning their use was given.

Note that the details of conducting the tests are given. The kinds of instruments used are identified by brand and model number. To avoid inconsistencies caused by personal bias, the same person ran the tests. This is similar to asking two cooks to put "some" pepper in a dish. How much is "some"? The amount may vary and so the taste may vary. But the same person is likely to use the same procedure each time.

4 The results obtained by using each of the five tests were given. In (a) no difference was found in the bleeding times of the two groups of subjects.

In (b) there was a difference. In a longer article, all of the bleeding times would be listed. Here, only the mean (average) time of blood clotting was given. The standard deviation (SD) for each group was also noted.

The results were then analyzed statistically and were shown to be significant. This means that there is very little possibility that the same results in the two groups would have been obtained by pure chance. This indicates that there is a real difference in the two groups.

In test (c) the results were given but no conclusions were drawn. The results were so varied that a statistical analysis could not be made. The only result was that the procedure was inconclusive.

Test (d) also showed a wide range of results but did not lead to any conclusions. Finally, test (e) showed a slight difference, but it was not statistically significant. This means that it could be a chance result.

BLOOD COAGULATION AND PLATELET FUNCTION IN RED-HAIRED MEN*

1 The small study reported here was an attempt to discover evidence for the legend that red-haired subjects bleed more easily than non–red-haired subjects.

SUBJECTS AND METHODS

2 In all, 49 male student volunteers were studied, 25 of whom were objectively classified as having red hair. The following methods have been described for distinguishing red hair from other colours:

(1) Measurement of ash content (Dutcher and Rothman, 1951).
(2) Microscopic observations of structure (Flesch and Rothman, 1945).
(3) Spectrophotometric methods (Reed, 1952; Barnicot, 1956).
(4) Pigment-extraction methods (Arnow, 1938; Rothman and Flesch, 1943).
(5) Fluorescence microscopy (Brunet, Kukita and Fitzpatrick, 1958).

Recently a more detailed examination of the extractable pigments in red hair has been performed by Boldt and Hermstedt (1967), which has shown that the previously described product from extraction of red hair is not homogeneous.

3 We decided to use the fluorescence microscopy method as being the most convenient. One hair from each subject was examined, using a Gillett and Sibert Conference microscope with filters 30–061, 30–062 and 10–285. All the samples of hair from subjects objectively classified as 'red-haired' showed yellowish fluorescence whereas no fluorescence was seen when hair from the remaining 24 subjects was examined.

The following five tests were then performed on each volunteer:

(a) Bleeding time (Duke, 1912).
(b) Whole-blood coagulation time (Lee and White, 1913).
(c) Screening thromboplastin generation test (Hicks and Pitney, 1957).
(d) Platelet count (Feissly, 1959).
(e) Measurement of platelet adhesiveness after addition of ADP (adenosine 5′ pyrophosphate) (Eastham, 1963, 1964).

Tests (b) and (c) were always done by the same person (C.M.T.) to avoid technical inconsistencies, and the blood or reagent for these tests was kept at constant temperature by use of a Seroblock heater. For test (e) a Coulter Counter Model A, fitted with a 70μ-orifice tube, was used and all dilutions for this test were performed by means of the Coulter Dual Dilutor.

RESULTS

4 (a) *The bleeding time.* No difference was found in the bleeding times of the two groups of subjects.

(b) *The whole-blood coagulation time.* This test did show a significant difference:

Non–red-haired subjects: mean 8.3 minutes (S.D. 1.15).
Red-haired subjects: mean 9.9 minutes (S.D. 1.25).

(c) *The screening thromboplastin generation test.* There was a wide scatter of results in both groups. It was found that the clotting time in red-haired subjects during the first few minutes of incubation was frequently as long as 180 seconds, whereas the longest time for the non–red-haired subjects was 60 to 70 seconds. Due to the wide variability it was not possible to evaluate these results statistically.

(d) *The platelet count.* There was a wide range of results in both groups of subjects and the values were frequently below those quoted as normal for healthy adults (Dacie and Lewis, 1963), but the results corresponded with those obtained using the Coulter Counter.

(e) *Platelet adhesiveness.* The mean percentage loss of platelets after aggregation by use of ADP was 36 per cent in non–red-haired subjects and 35 per cent in red-haired subjects. These results agreed with Eastham's results for this method using siliconized glass.

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