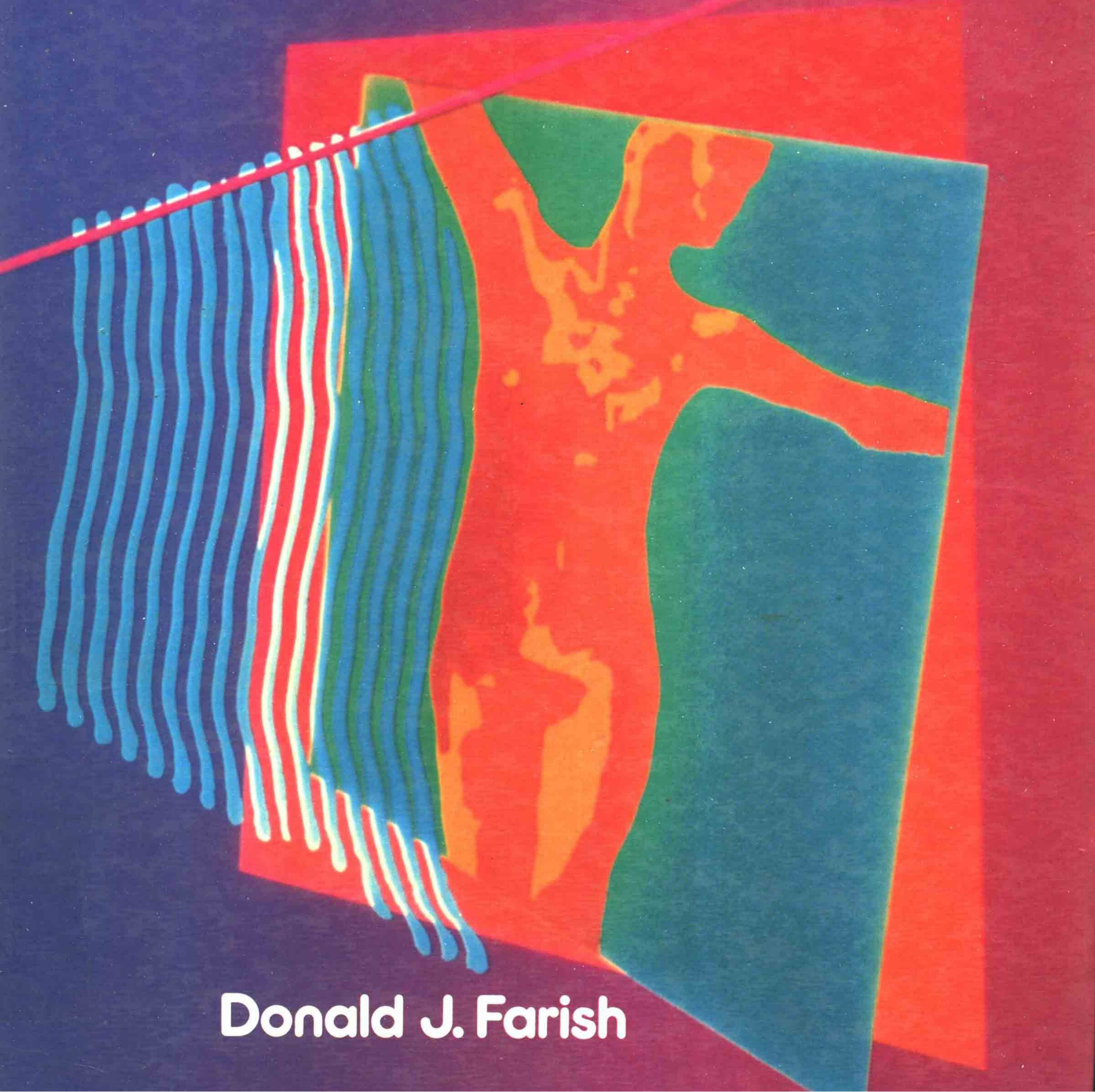
INTRODUCTION TO BIOLOGY
A Human Perspective



Donald J. Farish

INTRODUCTION TO BIOLOGY

Donald J. Farish
Sonoma State University

WG
Willard Grant Press, Boston

PWS PUBLISHERS

Prindle, Weber & Schmidt • Willard Grant Press • Duxbury Press •
Statler Office Building • 20 Park Plaza • Boston, Massachusetts 02116 • 617-482-2344

PWS Publishers is a division of Wadsworth, Inc.

Introduction to Biology: A Human Perspective was prepared for publication by the following people:

Production Editor: Robine Storm van Leeuwen
Interior and Cover Designer: Trisha Hanlon
Art Developer: Arthur Ciccone
Photo Researcher: Lauren Whittaker

Typesetting by Progressive Typographers; cover printed by Lehigh Press Lithographers; text printed and bound by The Maple-Vail Book Manufacturing Group

Electrographic cover print by Tom Norton

Library of Congress Cataloging in Publication Data

Farish, Donald J.
Introduction to biology.

Includes index.
1. Biology. 2. Human biology. I. Title.
QH308.2.F3 1984 574 83-25308
ISBN 0-87150-787-0

ISBN 0-87150-787-0

Printed in the United States of America
88 87 86 85 84 — 1 2 3 4 5 6 7 8 9 10

Preface

Introduction to Biology: A Human Perspective presents the basic concepts of biology for students who are not majoring in the subject. The course for which it is intended offers a difficult challenge, one of presenting science in a context that will appeal to nonscience students. Most texts available for this one-term course are either watered-down versions of larger works or collections of unrelated topics with little hint of biology as an intellectual discipline.

The focus in this text is on the human organism as a vehicle for illustrating the major biological principles, because students are familiar with their own bodies and are motivated to learn more about themselves and the immediate world around them. This focus allows the presentation of concepts in a reasonably complete, challenging way that will give students a solid grounding in biological principles.

To make the experience more profitable and permanent, several helpful tools have been included: introductory case studies, brief chapter introductions, enrichment boxes, chapter summaries, lists of key terms, study questions, a glossary, and a large number of illustrations.

Each chapter begins with a brief, real-life case study. This section is designed to draw students into the chapter, to help them apply what they learn to the common experience, and to pose questions they will be able to answer as they read the chapter. Chapter introductions offer a brief overview of what is to come, enrichment boxes give additional insight without breaking the continuity of the text material, and chapter summaries provide a capsule review of the ground just covered.

The excitement of biology as a science can be obscured by the large amount of terminology. Technical vocabulary has, therefore, been kept to a minimum and conceptual understanding rather than sheer memorization of terms has been emphasized. To help students test their understanding of material and of essential terms, however, I have included end-of-chapter lists of key terms and study questions and an extensive glossary at the end of the book.

A great deal of time and effort was invested in the selection and creation of functional as well as attractive illustrations since a careful integration of text and figures helps to enhance understanding.

A comprehensive instructor's manual, including transparency masters selected from the illustrations in the text, is available to adopters.

Acknowledgments

I have been fortunate to have the assistance of the reviewers listed below. Their help was invaluable, and I wish to extend my heartfelt thanks to them; without them, this book would be a different and inferior one. Thomas Capraro, Mohawk Valley Community College; Manus Donohue, North Texas State University; Ronald Hybertson, Mankato State University; Sol Karlin, Los Angeles Pierce College; Helen Lambert, Northeastern University; August Mueller, SUNY at Binghamton; Kenneth Prestwich, University of Florida.

I wish to thank Sinauer Associates, Inc. Publishers and Willard Grant Press for allowing me to use several illustrations from *Life: The Science of Biology* by William K. Purves and Gordon H. Orians.

Finally, I would like to acknowledge the efforts of Jean-François Vilain, biology editor, and Robine Storm van Leeuwen, production editor. For the past two years, they have kicked me less often than I needed but more often than I wanted. Without their help — and friendship — this book would never have been published. To them and to their colleagues at Willard Grant Press and especially to Art Ciccone, "art magician," I owe a debt of thanks.

Donald J. Farish

Contents

1 Development of Biological Principles

Life, Death, and History

Logic dictates that an introduction to any subject should begin with a brief look at how that subject is defined and how it has developed through history. However, in light of the dramatic impact of biology on our daily lives — for example, bacterial gene "factories" that synthesize human hormones, space probes for extraterrestrial life, the health and ecological hazards of mercury and DDT in the food chain — spending time on a historical perspective may seem foolish and unnecessary. Yet biology has had a fascinating, if often checkered, history, full of incredible insights and equally incredible errors. Indeed, from the lofty vantage point of the twentieth century, we can look back over more than two thousand years and watch biology as it progressed, like a rat in a maze, erratically but ultimately successfully.

In the arts many people find modern painting, music, and literature inferior to the achievements of earlier times. Science, however, has progress as its very hallmark. Despite many false starts, science builds on earlier discoveries in a cumulative fashion. As a consequence, scientists of past generations, though greatly respected in the scientific community, have been supplanted in the public mind. They enjoy none of the reverence accorded to great artists, composers, and writers of the past. The scientific intellects of Galileo, Newton, and Pasteur will perhaps never be surpassed; however, because every high school senior knows more science than any of those historical greats ever knew, we find it difficult to appreciate how much they shaped the way we see ourselves and our world. Therefore, to acquire a proper perspective of science in general, and of biology in particular, we must undertake a historical assessment. First, however, we need to define the limits of our study by examining what biology is and what it does.

What Is Life?

The traditional definition of biology, "the study of life," tells us very little because the term *life,* like the term *pornography* (as the Supreme Court found), is widely used but impossible to define precisely. We intuitively distinguish living things from nonliving things, but deciding when one becomes the other is more difficult. Heartbeat is the traditional medical measure of life; however, consider what happens when a person is shot through the heart. Is he dead because his heart has stopped beating? Suppose he is immediately put on a heart-lung machine that keeps his blood circulating. Is he still dead? If he is given a heart transplant, has he been "brought back to life"? Heartbeat is a useful indicator of life, but its presence or absence does not tell us much about what life really is. Moreover, heartbeat is a meaningless test for many organisms. Trees, mushrooms, and protozoa have no hearts, yet we recognize them as being alive.

Box 1-2 Louis Pasteur and Spontaneous Generation

The recentness of the use of the scientific method is illustrated by the long debate over **spontaneous generation**. For thousands of years people believed that, given the proper environment, living organisms could arise directly from nonliving materials. Frogs came from mud; flies developed from spoiled meat; mice emerged from piles of dirty clothing left in a dark place. As ludicrous as these notions appear today, it was not until the nineteenth century that the French scientist Louis Pasteur finally disproved the theory of spontaneous generation.

To be sure, many scientists had rejected spontaneous generation even before Pasteur's experiments, and efforts had been underway for two hundred years to prove the notion false. However, proving a negative is very difficult, and the scientists efforts were never completely satisfactory. One early scientist noted that meat protected by gauze did not "develop" flies as did uncovered meat. Perhaps not, said the opponents, but the meat still spoiled, and with a microscope, viewers could see tiny organisms crawling around inside.

Disproving the spontaneous generation of microorganisms was a larger challenge, but some time later an industrious scientist heated broth in a flask and then sealed the neck of the flask. Unlike broth in an open flask (the control), the broth in the sealed flask developed no microorganisms. "Unfair!" cried the supporters of spontaneous generation. "Cutting off the supply of air prevents the 'vital force' needed to generate life from reaching the broth!" (Undiscouraged, the resourceful fellow gave up science and founded the canning industry.)

Louis Pasteur also experimented with broth in a flask, but rather than sealing the flask, he simply drew it out in an S-shape. It was therefore open to the air, but of course spores and bacteria in the air settled in the bottom of the S, and the broth remained pure. When the S was broken off, however, microorganisms did develop in the broth. Thus, Pasteur's experiments showed that the shape of the flask, not the condition of the broth, prevented the growth of microorganisms.

It seems incredible that such a simple experiment should have taken two centuries and one of science's greatest minds to devise. Our incredulity however, is based on the fact that experiments, controls, and the scientific method have become so completely a part of our culture.

---

behavior among males of a particular species of fish. The investigator observed aggressive behavior only during the mating season, and only at that time did the males develop a bright red patch on their bodies. He hypothesized that this red patch must be the cue that males used to recognize and then attack other males that invaded their territory. Initial experiments with carved models of the fish supported the hypothesis, the model was attacked if it had a red patch and ignored if it did not.

However, to the scientist's consternation his control males, held in isolation from each other and from any red coloring, occasionally showed aggressive behavior without any apparent cue. In their frenzy they would hurl themselves against the glass of the aquarium. After verifying that the lighting prevented the fish from seeing their own

Replication can be a particular problem when the hypothesis is not that A *causes* B but only that A *increases the likelihood* that B will result. Consider, for instance, the notion that birth control pills increase the likelihood of spontaneous blood clots that lead to heart attacks and pulmonary embolisms (see chapter 6). Because millions of women survive years of taking the pills, the pills obviously do not "cause" blood clots to form in any absolute sense. Rather, there is evidence that an extraordinarily rare event — spontaneous formation of blood clots in women of childbearing age — becomes somewhat more frequent in women who take birth control pills. This hypothesis was not easy to verify. Because the incidence of clotting was so low, even with hundreds of thousands of women being surveyed and monitored, scientists at first had grave reservations about the validity of their conclusion. Repeated studies on still larger populations ultimately confirmed the initial hypothesis. Ironically enough, but for the extreme popularity of the pill, the population of users might never have been large enough to permit a final conclusion.

Cause and effect versus correlation. The example of birth control pills also provides an object lesson in the role of experiment in the scientific method. In the testing of a hypothesis, all the subjects of the experiment need not show a particular result. Rather, the experimental population need show only a statistically significant difference from the control population. When this difference is small, however, scientists may be uncertain whether the results were actually caused by the experimental procedure or were merely coincidentally correlated with it. For example, the belief that smoking causes lung cancer is fervently held by many scientists and reformed smokers and is fervently disavowed by people who continue to smoke. Is there a **cause-and-effect relationship** between smoking and cancer, or is the relationship merely a **correlation** — that is, are smokers people who were likely to develop cancer anyway, regardless of whether they smoked?

The evidence is now very strong that people who smoke cigarettes for many years exhibit a rate of lung cancer substantially higher than the rate of lung cancer in nonsmokers. Recognition of this fact has been hindered because cancer generally develops very slowly — that is, there is a long lag period between the cause and the effect.

The question of the connection between smoking and lung cancer is complicated by the problems in experiments involving people. A satisfactory experimental design to prove or disprove the hypothesis might be to take 1,000 pairs of identical twins, rear them identically, and force one twin in each set to smoke but prohibit the other from doing so. If the hypothesis that smoking leads to an increased rate of lung cancer is valid, after twenty years the smoking twins should show

Box 1-3 The Evils of Saccharin

One of the touchiest areas of the scientific method is **extrapolation,** the extension of findings from one set of experimental circumstances to a completely different (but logically derived) set of circumstances. All scientific conclusions represent one level of extrapolation. For example, if we observe that dropping an individual through a trapdoor with a noose around his neck causes his neck to break, we can conclude that such an action will likely cause any person's neck to break. We don't have to test the design endlessly to accept the conclusion.

Accepting extrapolations from one species to another is more difficult. Several years ago a group of scientists fed 100 rats very high doses of the artificial sweetner saccharin, and 3 of the rats developed cancer of the bladder. Because the Delaney clause of the Food, Drug and Cosmetics Act prohibits the use of any food additive "if it is found to induce cancer when ingested by man or animal" (a tacit acceptance of the correctness of extrapolation), the FDA initiated steps to ban saccharin.

Many people were outraged at the proposed ban. They objected that the levels of saccharin fed to the rats equaled a human dose of 800 bottles of saccharin-sweetened soft drinks a day. Moreover, they pointed out, saccharin had been in use for more than eighty years and apparently had not caused an epidemic of bladder cancer. Also, saccharin was a valuable dietary aid for diabetics and for obese individuals. Ultimately the saccharin question became something of a political football. What the furor illustrates, however, is the problem that commonly results when findings that hold true for other species are extrapolated to humans. Often the correctness of the extrapolation is subject to intense and frequently unending debate, with no final resolution.

more lung cancer than the nonsmoking twins. Of course, such an experiment would be impossible, and an alternative — for example, using monkeys or other experimental animals — would probably not satisfy the doubters. Thus, the controversy is unlikely to be laid to rest until the last smoker is.

Applying the Scientific Method to Contemporary Problems

Increasingly our society will be called on to make judgments regarding possibly injurious materials, and the evidence will often be equivocal. Future problems are likely to involve low-incident effects or effects distantly related in time to the cause. For example, should fluorocarbons be banned from aerosol cans because they cause the ozone layer to break down? Should sodium nitrite be prohibited in the preservation of meats because it may cause cancer? (Or are we willing to accept the alternative — without sodium nitrite or some other preservative, the risk of food poisoning rises substantially?) Did Agent Orange, used extensively during the Vietnam War to defoliate trees, promote the incidence of cancer in GIs unfortunate enough to be on the ground during the spraying? Answers to these kinds of questions depend on using and interpreting the scientific method, and these issues are only a