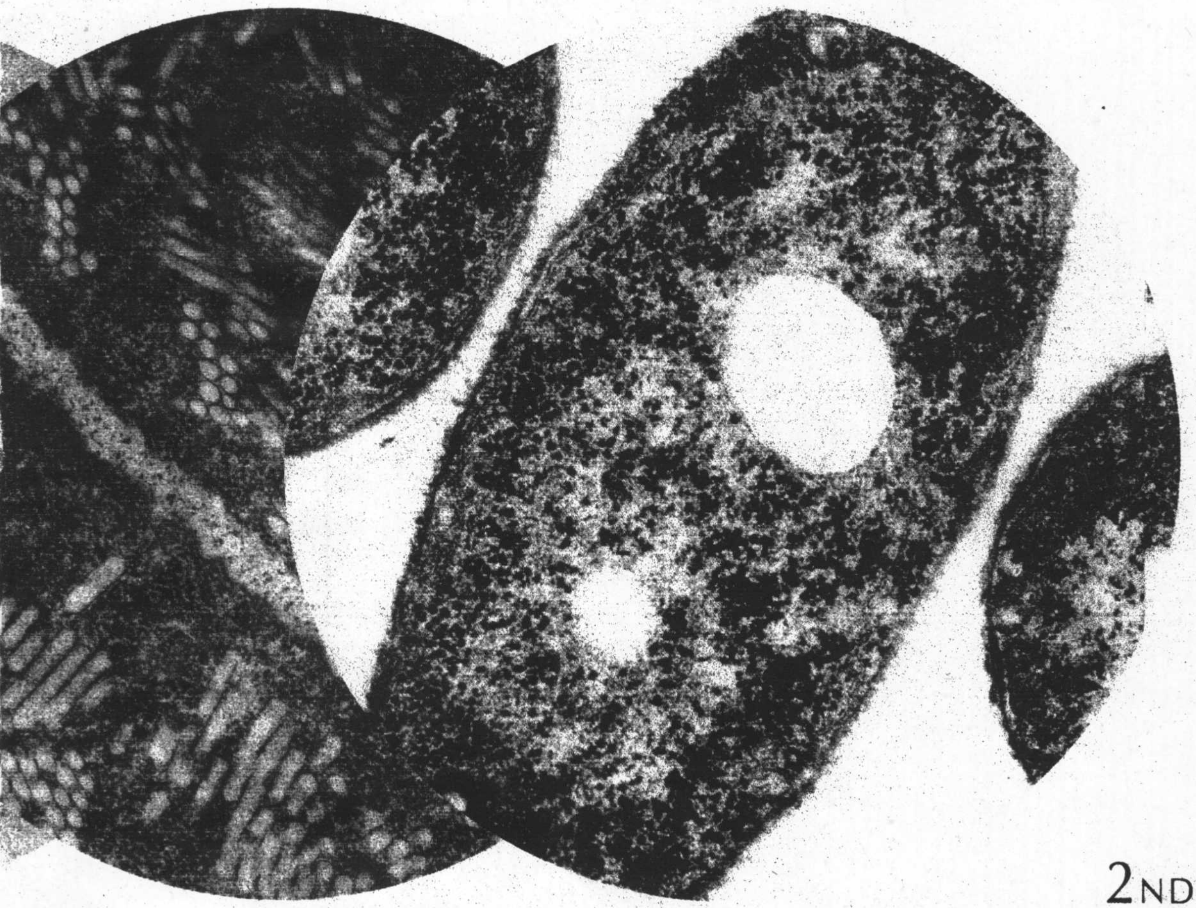
Ronald M. Atlas

MICROBIOLOGY

Fundamentals and Applications

2ND EDITION



2ND EDITION

MICROBIOLOGY

Fundamentals and Applications

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Cover photo: Culture of *Pseudomonas* and *E. coli* on blood agar.
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Preface

Overview

Microbiology: Fundamentals and Applications covers the broad vistas of microbiology, providing students with a basis for understanding the various aspects of this field. It is intended for students who require a knowledge of microbiology for their future careers, as well as for students who desire a knowledge of microbiology for use in their daily lives. The depth of topic treatment is sufficient to satisfy and to stimulate student interest in the exciting field of microbiology.

The book is intended to be comprehensive and to meet the varied teaching needs of different institutions. Undoubtedly, there is more material in this text than can be reasonably handled in a one-semester course. Instructors may pick from the various chapters to meet their own needs. The text is designed to be flexible so that the order of chapters and topics covered are subject to the instructor's creativity. To aid in this endeavor, the first weight headings have been numbered for ease in assigning individual sections. Students can supplement the coursework by reading topics of interest that are omitted by the instructor from the formal class presentation.

There has been a general updating of material throughout this edition. Topics such as biotechnology and acquired immune deficiency syndrome have been expanded, as these are at the forefront of public attention in microbiology today. In these areas, both fundamental background information and applied aspects have been added to increase understanding.

General Organization of the Second Edition

Each chapter has the following general structure:

- Text of chapter
- Postlude
- Suggested supplementary readings
- Study questions
- Situational problems

The book is organized from the basic to the practical. Following an examination of the historical development of microbiology and the basic techniques of the microbiologist, the fundamental aspects of microbiology are examined in sections on structure, metabolism, genetics, and taxonomy. These sections build from the subcellular to the whole-organism level and establish the fundamental aspects of microbiology needed to understand the practical or applied aspects of microbiology covered in later chapters. Later chapters examine the practical ecological, industrial, and medical aspects of microbiology. There is a balance between the fundamental and applied aspects of microbiology.

The book includes coverage of both the eukaryotic and prokaryotic microorganisms, and, although the emphasis is undoubtedly placed on bacteria, eukaryotic organisms and viruses are also thoroughly covered. By comparing the similarities and differences among viruses, bacteria, and eukaryotic microorganisms, the student will develop an understanding of the basis for some of the applied aspects of microbiology, such as the use of antimicrobial agents in treating infectious diseases.

Several major changes have been made in the second edition of the text. There has been a major reorganization of chapters. The first chapter of the text still concerns the scope of microbiology and some of the early historical developments, but it has been greatly abbreviated to avoid overwhelming students with the history of all fields of microbiology and the associated terminology with these new subjects. Sections of the original historical discussion have been added to the postludes of the appropriate chapters.

The second chapter of the text covers microscopy and the third discusses the structures of prokaryotic and eukaryotic cells. The retention of a discussion of eukaryotic cells is critical for comparative purposes so that students understand the fundamental differences between prokaryotes and other organisms.

The growth and reproduction of bacteria, originally discussed in the chapter with viral replication and growth of eukaryotes, is moved towards the beginning of the book as the initial chapter on microbial metabolism. Bacterial reproduction is now combined with the discussion of nutrition. This chapter is followed by the discussion of microbial metabolism which, in turn, is followed by the discussion of microbial genetics.

The next section, entitled Survey of Microorganisms, begins with the chapter on virology. The consolidation of most of the material on virology into a single chapter on the viruses is perhaps the greatest organizational change between the first and second editions. Material on the structure of viruses, the replication of viruses, and viral taxonomy is included in this unified chapter on virology, which bridges the gap from the molecular-level discussion of the preceding chapters to the whole-organism level that takes place in the following chapters on bacterial taxonomy and the classification of eukaryotic microorganisms. Information on reproduction of eukaryotic microorganisms, previously found together with the discussion of bacterial and viral reproduction, has been included in the chapter on taxonomy of eukaryotes. This change should accommodate users of the book who do not wish to include eukaryotes in their discussions.

The survey of microorganisms section is now followed by coverage of environmental microbiology. The earlier placement of this section is aimed at tying this information more closely to the discussion of fundamental aspects of microbiology. The environmental section now has four chapters; the additional chapter is concerned with environmental effects on microorganisms and the distribution of microbes in nature. A chapter devoted to biogeochemical cycling and population interactions, one concerning agricultural microbiology, and one concerning water quality and pollutant biodegradation are retained in this section.

The environmental section is followed by the food and industrial microbiology section which in turn is followed by the medical section, which includes a discussion of immunology. Placement of medical microbiology at the end of the book allows instructors who do not cover this topic to easily omit it from their courses and students who want to use this material as a reference source can easily find the appropriate information. Within the medical section, the chapter on clinical microbiology that appeared in the first edition has been eliminated and the information incorporated into a unified chapter on prevention, diagnosis, and treatment of diseases caused by microorganisms.

Special Features

Analytical Process Boxes Within most chapters where methodological processes are discussed, analytical boxes have been added. These analytical boxes set off material, describing the procedures used by microbiologists to gain the information on the topics being discussed.

Discovery Process Boxes The discovery boxes, a popular feature of the first edition, have been retained and several new ones have been added. These boxes augment the figure captions, illustrating how discoveries were made. They highlight the paths scientists have followed in developing the knowledge that fills this text.

Illustrations The book is elaborately illustrated, and each figure is accompanied by a clear and detailed figure legend. There has been a thorough review and upgrading of art, including additional use of color and use of overlay labels for many micrographs. These enhance the use of illustrations as teaching aids.

Key Terms Within the text, key terms have been highlighted. These terms are defined in the glossary and in the text near where they are introduced. Succinct definitions of key terms permit students to continue reading and understanding the section without having to fully grasp every nuance of a term or to turn to the glossary if they are unfamiliar with a term. Every effort has been made to ensure that terms and concepts are clearly defined.

Postludes Each chapter ends with a postlude that summarizes and places the information discussed in the chapter in proper perspective. As noted, historical information about the material covered in each chapter has been added to the postludes. The postludes remain more than simple summaries, attempting to place the information discussed in the chapters into a broader context of history and science.

Supplementary Readings List There has been a thorough updating of the suggested reading lists to include the latest articles. This list is meant neither to be complete, nor of great depth, but to supplement the text for more advanced courses and to sustain the interest of the student who finds a particular topic relevant to his or her purpose for having enrolled in an introductory microbiology course.

Questions Each chapter has a set of review questions intended to allow students to test their own comprehension of the material they have just examined.

Situational Problems Situational problems have been added at the end of each chapter to cause students to think and to develop an in-depth understanding of microbiology. These problems should be challenging and interesting to students.

Glossary of Microbiological Terms An extensive glossary has been included to help the student understand the information of the book. Key terms highlighted in the text when first introduced are included in the glossary.

Glossary of Bacterial Genera There is an abridged glossary of bacterial genera that can be used as a handy reference for the descriptions and key features of the more common bacteria.

Appendices The appendices include the metric system and a review of basic chemistry. The chemistry appendix can act as review or remedial material to ensure that students have ready access to the chemical principles they need to understand microbiology.

Supplements

Laboratory Manual "Experimental Microbiology" by A. Brown, K. Dobra, L. Miller, and R. M. Atlas. This laboratory manual provides an extensive compilation of laboratory exercises that can be used for introductory laboratory courses.

Instructor's Manual Outlines of text chapters and extensive listing of audiovisual material that can be used with each chapter.

Laboratory Instructor's Manual Helpful hints for laboratory exercises and sources of needed materials.

Transparencies Collection of transparencies from the text that can be used to illustrate lecture material.

Slides Collection of 35 mm slides that can be used to illustrate lecture material.

Test Bank Computerized collection of test questions compiled by H. Peery that can be used for preparing exams.

Computer Aided Instructional Package "Micro-micro" by J. Snyder, G. Weinberg, and R. M. Atlas. This computer aided instructional package contains 42 lessons in general and medical microbiology. It can be run on Apple II series and IBM PC compatible microcomputers. The lessons can be used to review topics, such as enumeration of microorganisms, as well as to learn more advanced topics, such as specific areas of clinical microbiology.

Acknowledgments

Many individuals contributed to the writing of this book, and their efforts indeed are appreciated. Many of my colleagues, to whom I am indebted, contributed micrographs. Carl May, of the Biological Photo Service, found many of the photographs that help illustrate this text. I am especially grateful to the following reviewers for their comments and helpful suggestions that have aided greatly in the writing of this book and development of the second edition:

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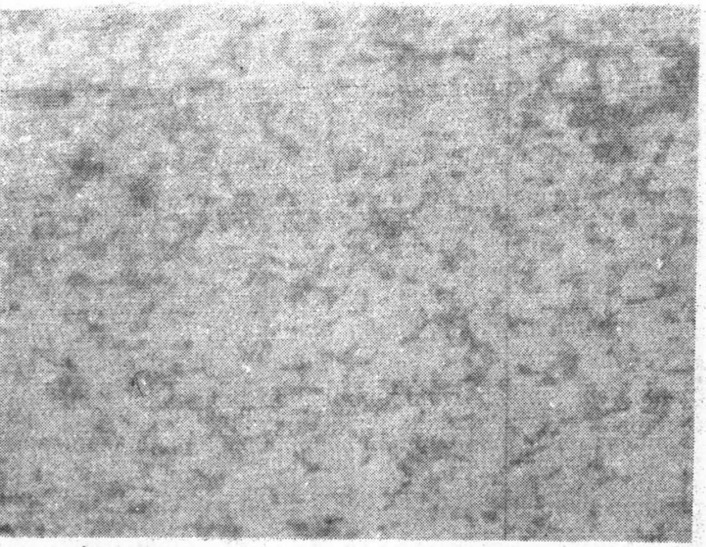
R. M. A.



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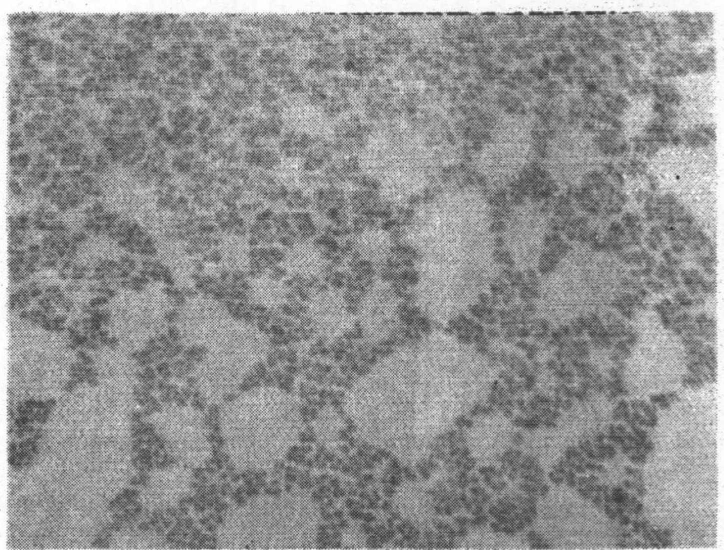

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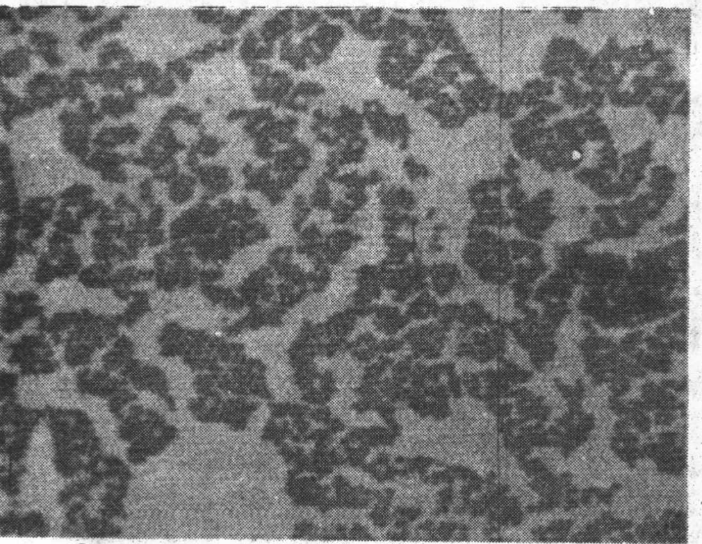

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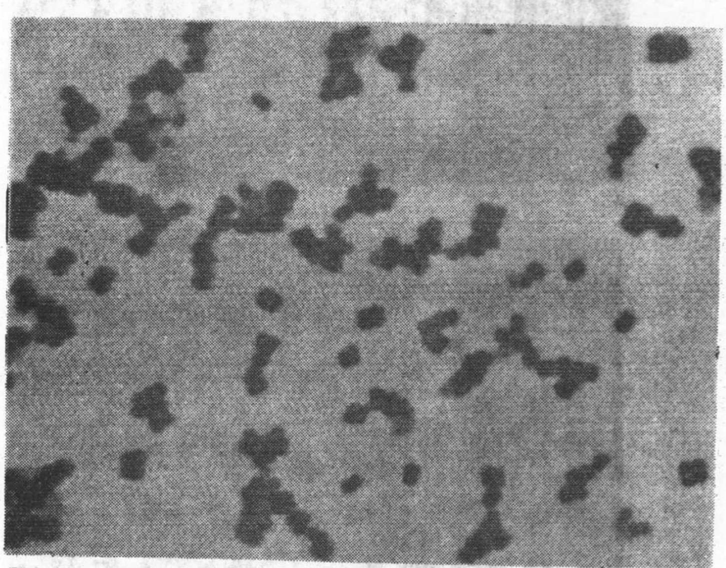

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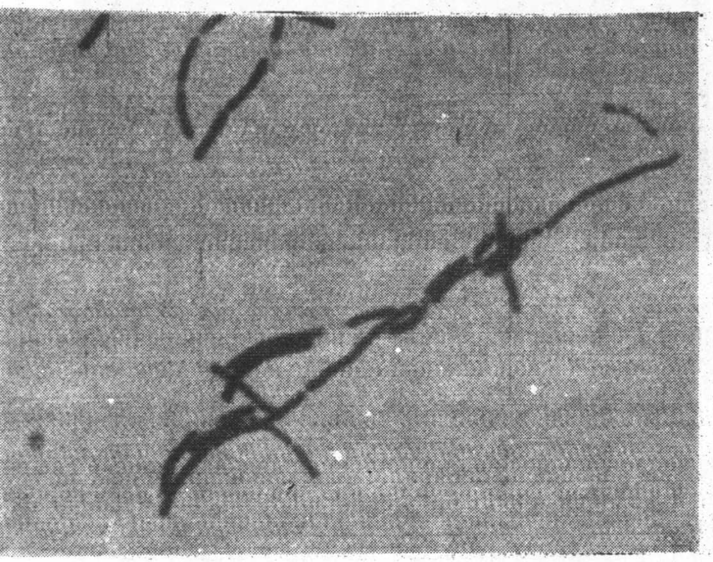

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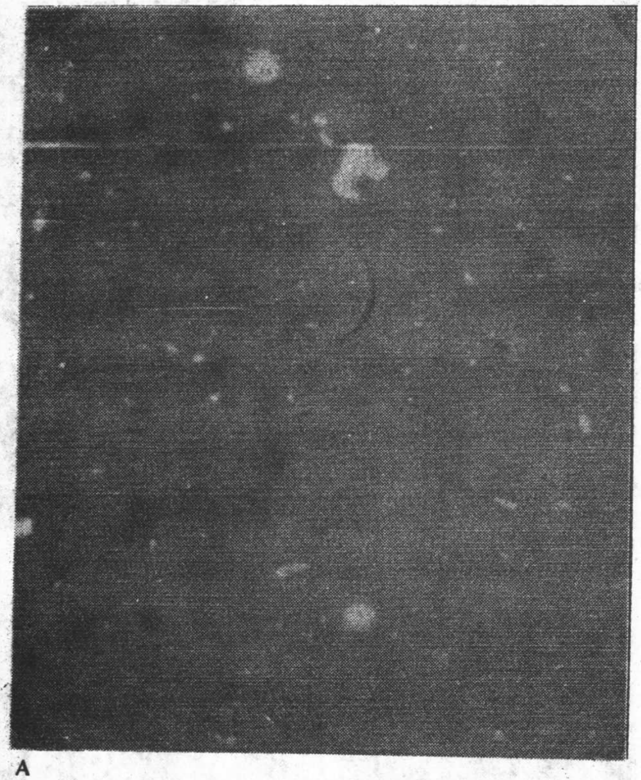
Plate 1 **(A)** Micrograph of the Gram negative, rod-shaped bacterium *Escherichia coli*. (From BPS—Leon J. Lebeau, University of Illinois Medical Center) **(B)** Micrograph of *Acinetobacter*, a Gram negative coccobacillus. (From BPS—Leon J. Lebeau, University of Illinois Medical Center) **(C)** Micrograph of *Staphylococcus*, a Gram positive coccal-shaped bacterium that forms grapelike clusters. (From BPS—Leon J. Lebeau, University of Illinois Medical Center) **(D)** Micrograph of a *Micrococcus* species that forms tetrads of coccal-shaped cells. (From BPS—Leon J. Lebeau, University of Illinois Medical Center) **(E)** Micrograph of *Bacillus subtilis*, a Gram positive rod-shaped bacterium that produces endospores. (From BPS—Paul Johnson, University of Rhode Island)



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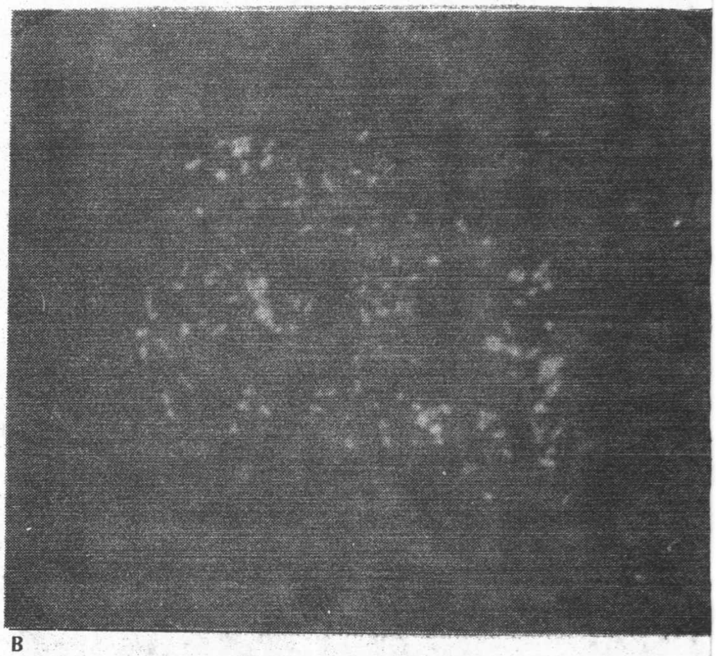

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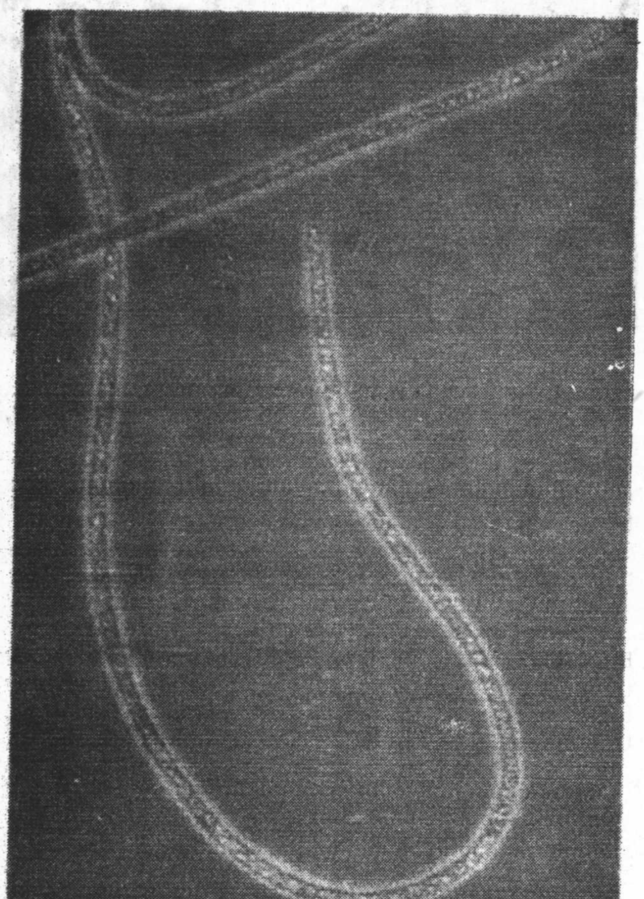

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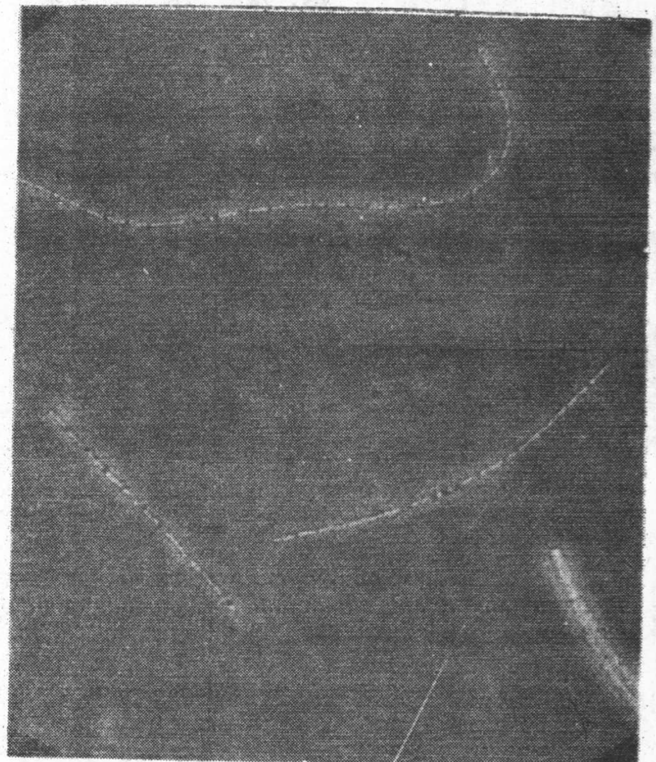

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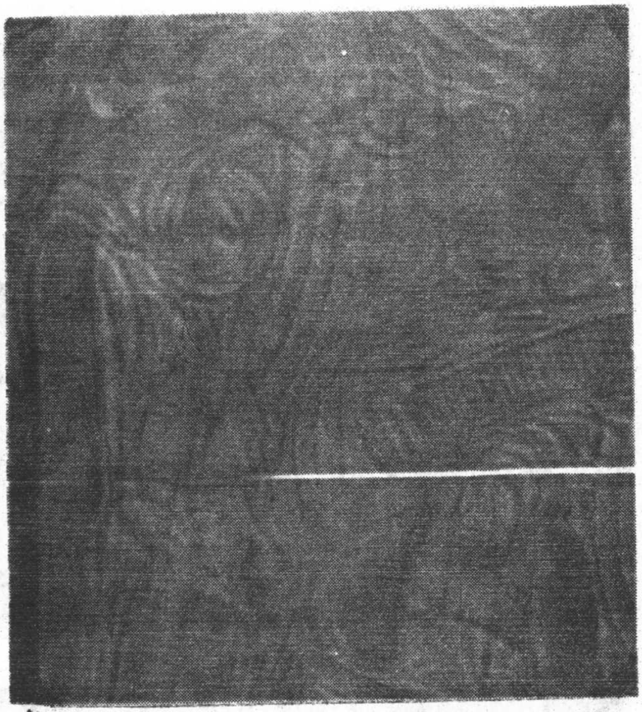
Plate 2 **(A)** Micrograph showing marine bacteria stained with DAPI and viewed by epifluorescence microscopy. (From BPS—Paul Johnson, University of Rhode Island) **(B)** Microcolony of bacteria stained with acridine orange and viewed by epifluorescence microscopy. (From BPS—Paul Johnson, University of Rhode Island) **(C)** Phase contrast micrograph of the bacterium *Beggiatoa*. (From BPS—Paul Johnson, University of Rhode Island) **(D)** Phase contrast micrograph of the bacterium *Thiothrix*. (From BPS—Paul Johnson, University of Rhode Island)



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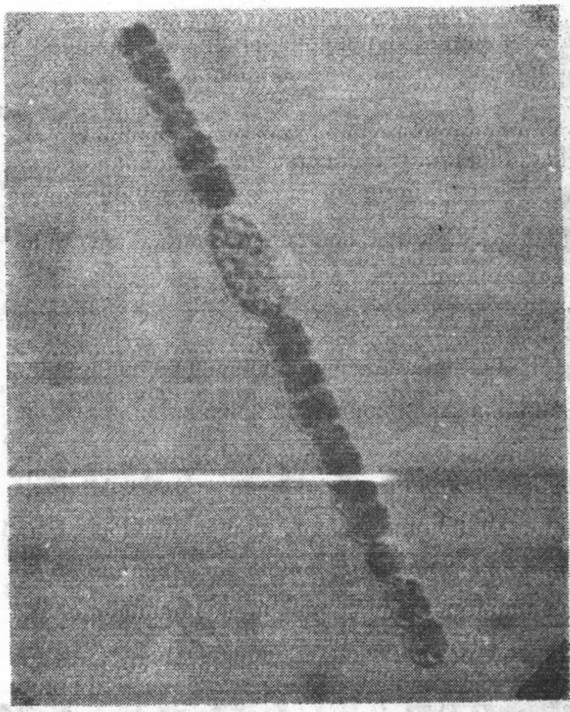

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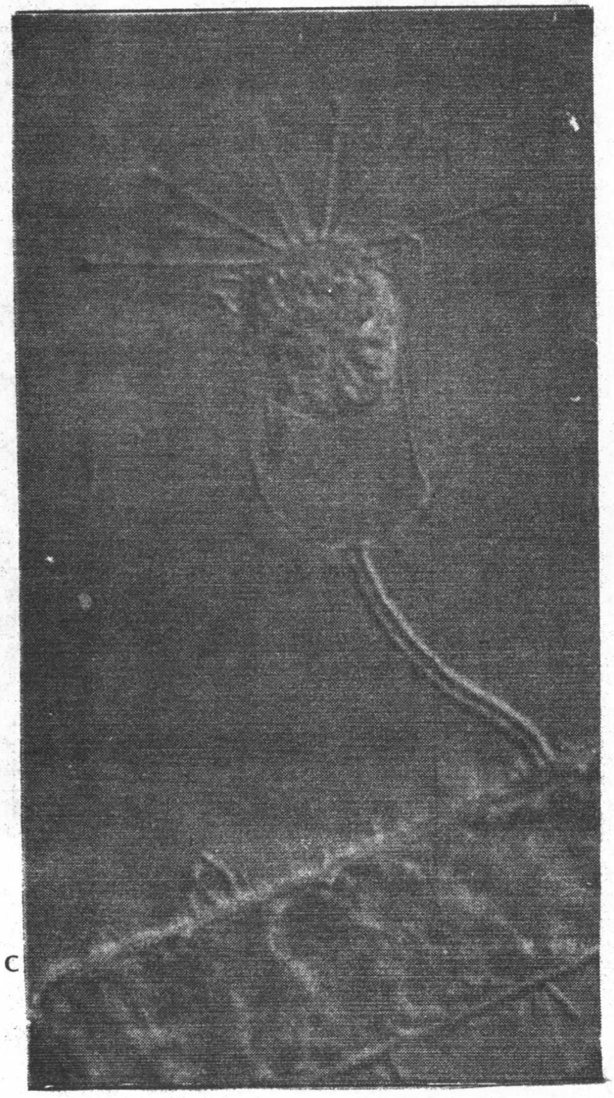

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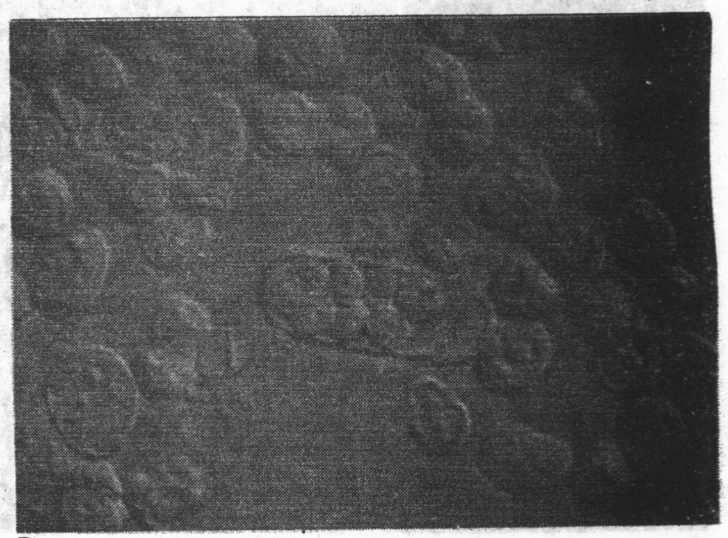

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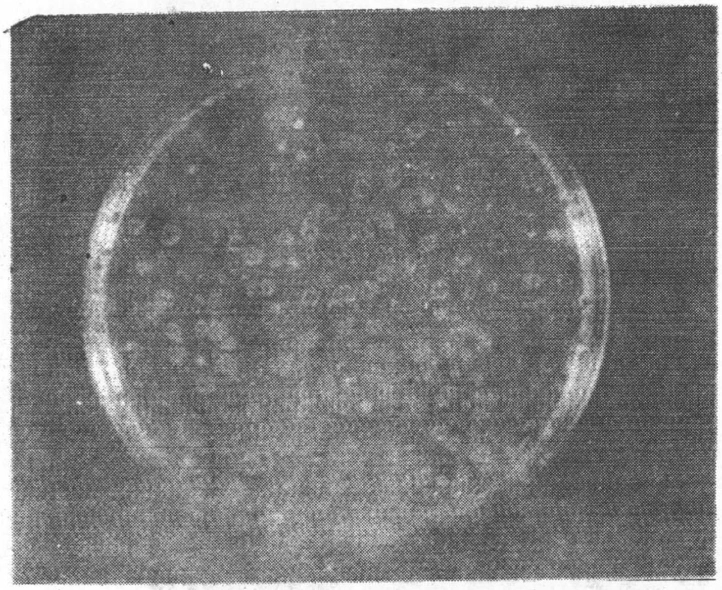
Plate 3 **(A)** Filaments of the cyanobacteria *Lyngbia* and *Oscillatoria* viewed by Nomarski interference microscopy. *Lyngbia* is larger than *Oscillatoria*. (From BPS—Paul Johnson, University of Rhode Island) **(B)** Micrograph of *Anabaena*, a filamentous cyanobacterium that forms heterocysts, viewed by Nomarski interference microscopy. (From BPS—Paul Johnson, University of Rhode Island) **(C)** Nomarski differential interference micrograph of the protozoan *Parcineta* on the alga *Spongomorpha*. (From BPS—Paul Johnson, University of Rhode Island) **(D)** Nomarski differential interference micrograph of the yeast *Schizosaccharomyces* containing ascospores. (From BPS—J. Robert Waaland, University of Washington)



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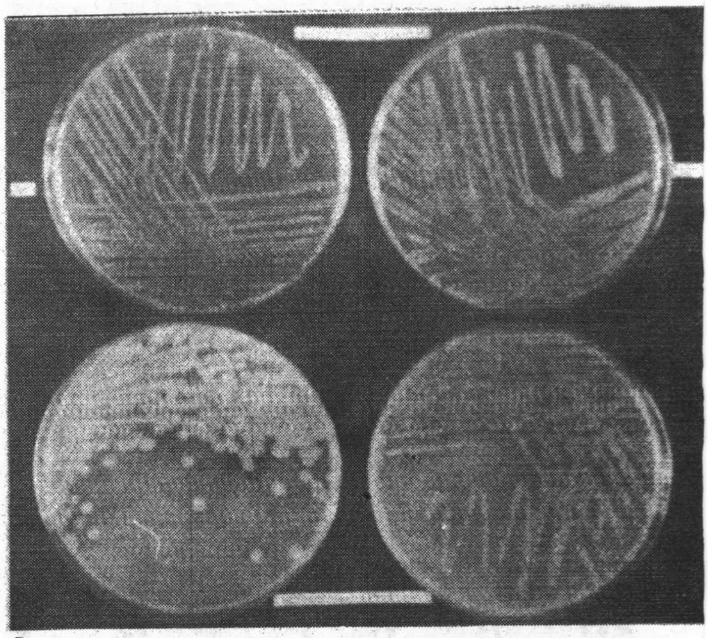

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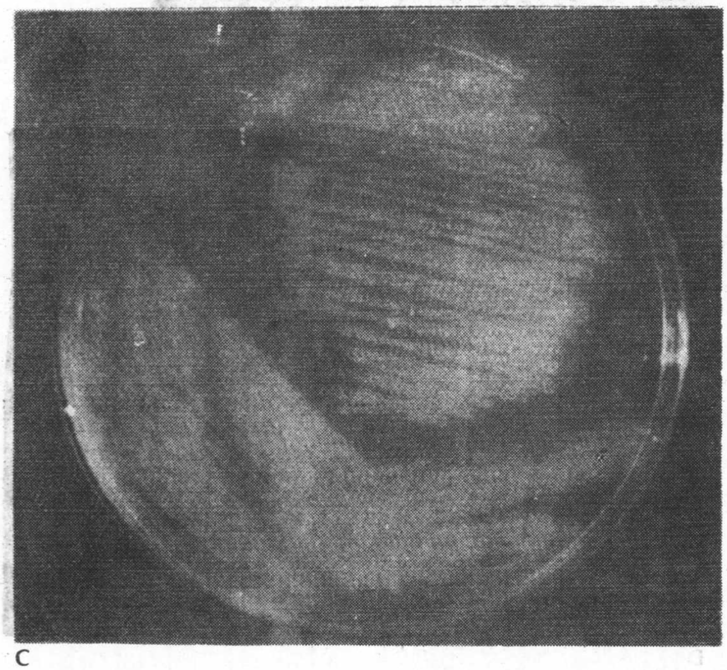

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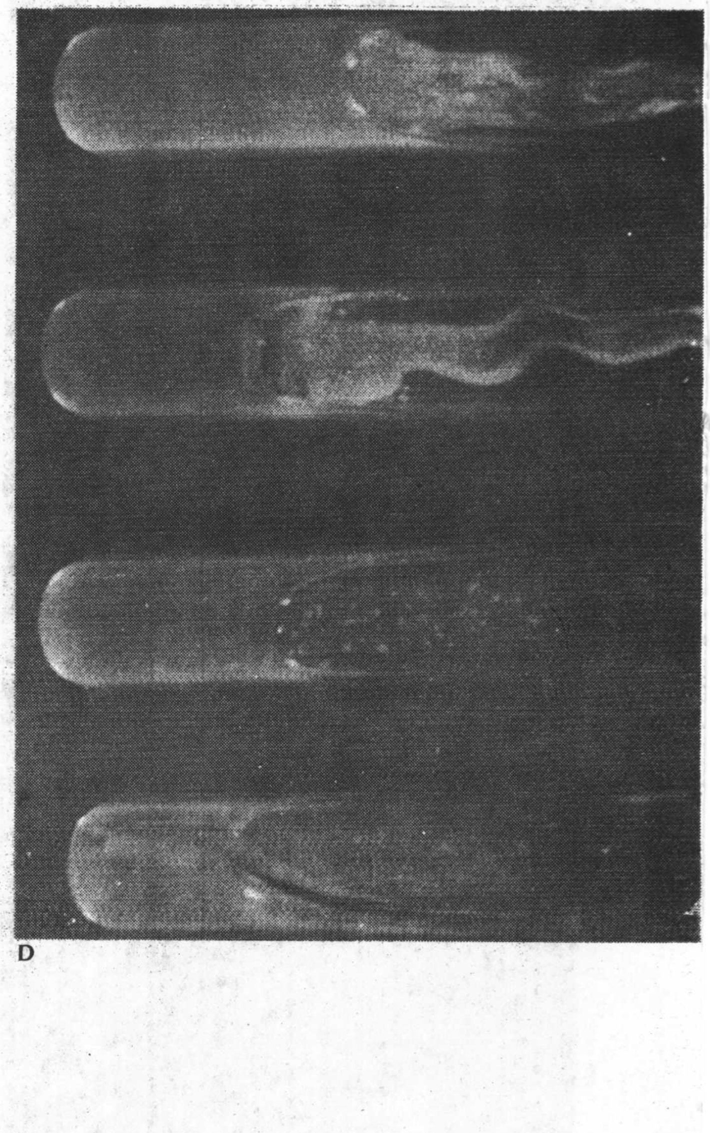

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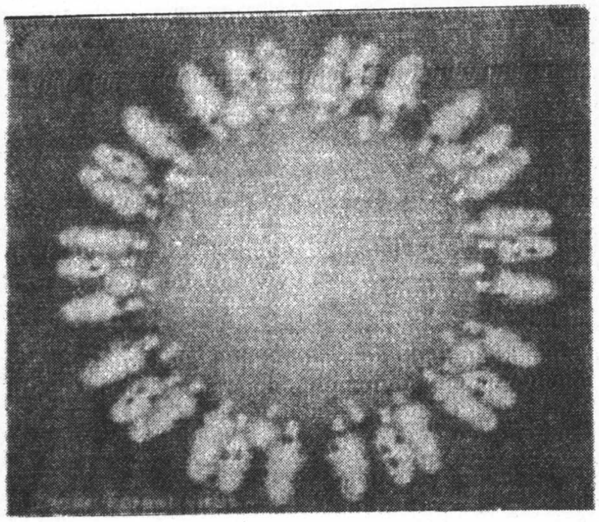
Plate 4 **(A)** Pour plate with colonies of *Serratia marcescens* (red) and *Escherichia coli* (grey). (From BPS—B. J. Miller) **(B)** Streak plates showing pigment production by *Serratia marcescens* (top two) and *Pseudomonas aeruginosa* (bottom two) grown at 25°C (left) and 37°C (right). (From BPS—R. L. Miller, BioTechniques Laboratories) **(C)** Plate showing fluorescent growth of *Pseudomonas aeruginosa*. (From BPS—Leon LeBeau, University of Illinois Medical Center) **(D)** Tubes with media containing different sugars inoculated with *Neisseria gonorrhoeae*. This bacterium ferments glucose (top tube that turns yellow due to acid production) but not maltose, sucrose, or lactose (remaining tubes that remain red indicating no acid production). (From BPS—Leon LeBeau, University of Illinois Medical Center)



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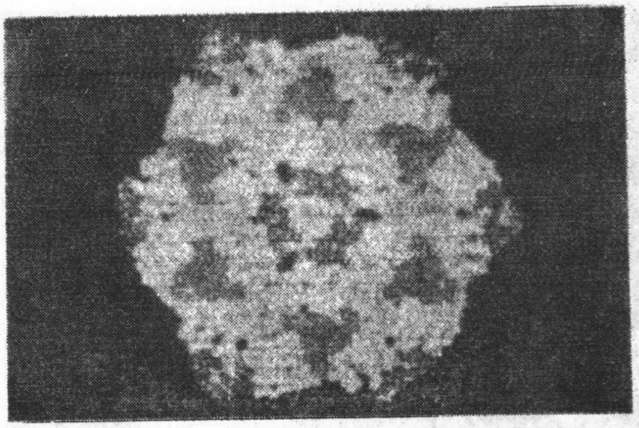

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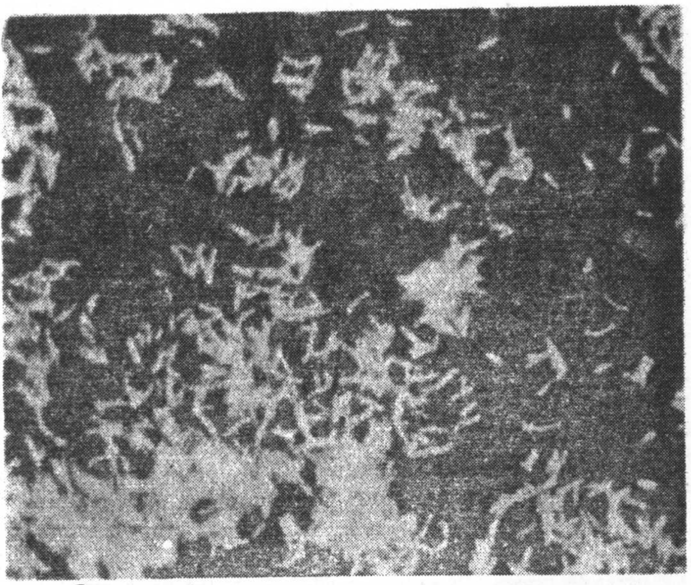

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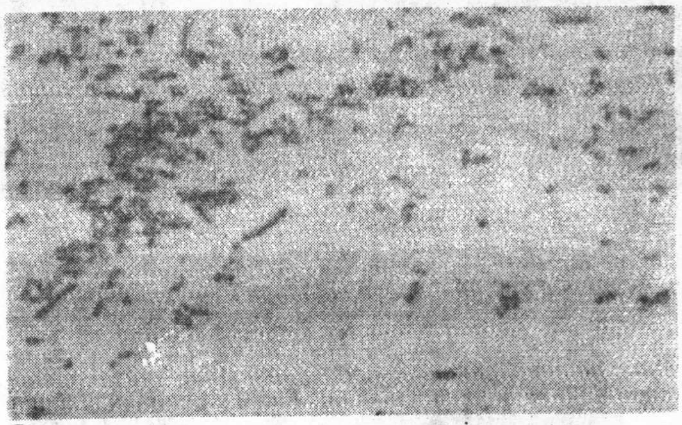

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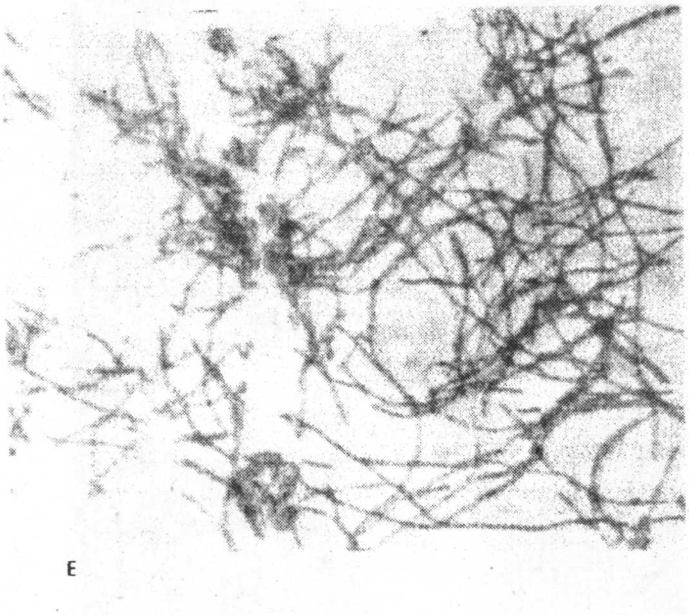

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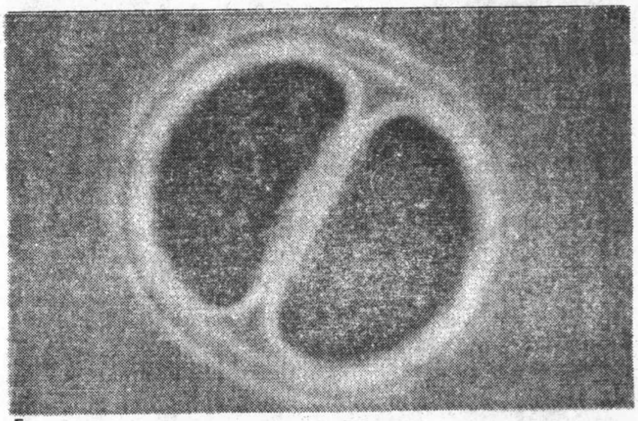

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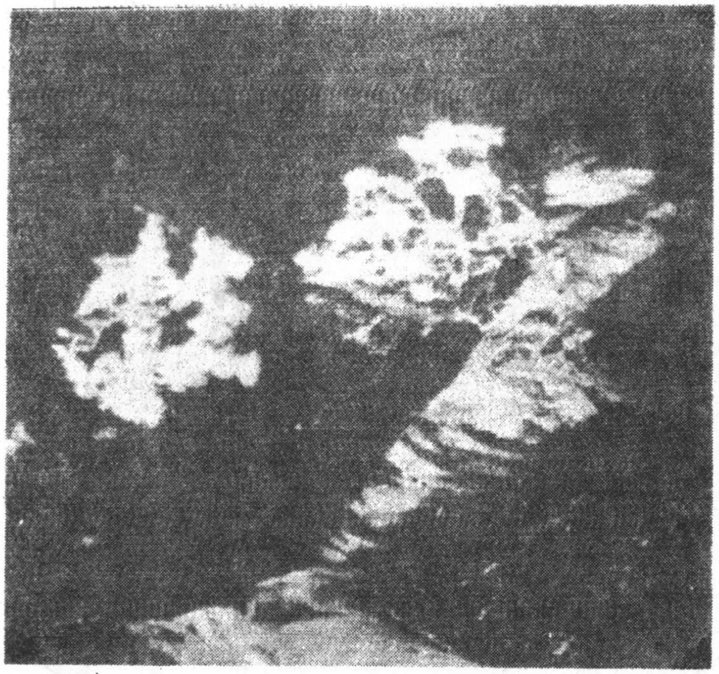
Plate 5 **(A)** Color-enhanced computer image of a cross section of Semliki Forest virus. (R. Feldmann, National Institutes of Health) **(B)** Color-enhanced computer image of a front view of Southern bean mosaic virus. (R. Feldmann, National Institutes of Health) **(C)** Micrograph of *Mycobacterium tuberculosis* stained with auramine 0 and viewed by fluorescence microscopy. (From BPS—R. L. Moore, BioTechniques Laboratories) **(D)** Gram stain of *Bacteroides fragilis*. (From BPS—Leon LeBeau, University of Illinois Medical Center) **(E)** Gram stain of *Lactobacillus* sp. (From BPS—Leon LeBeau, University of Illinois Medical Center) **(F)** The cyanobacterium *Chroococcus turgidus*. (From BPS—J. Robert Waaland, University of Washington)



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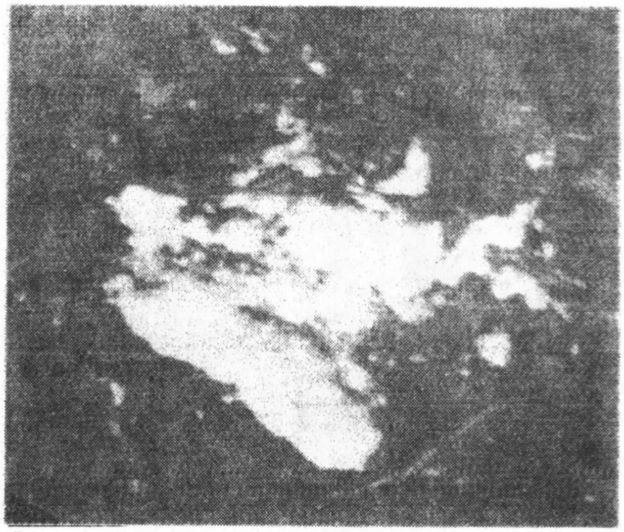

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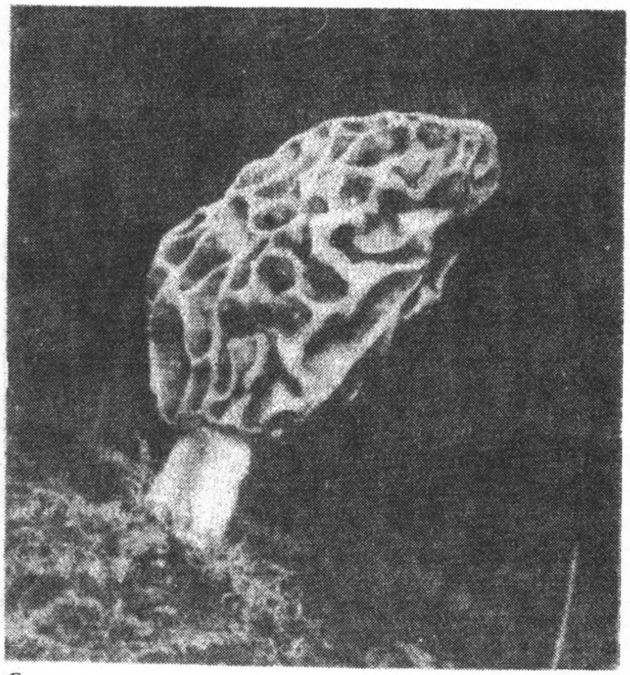

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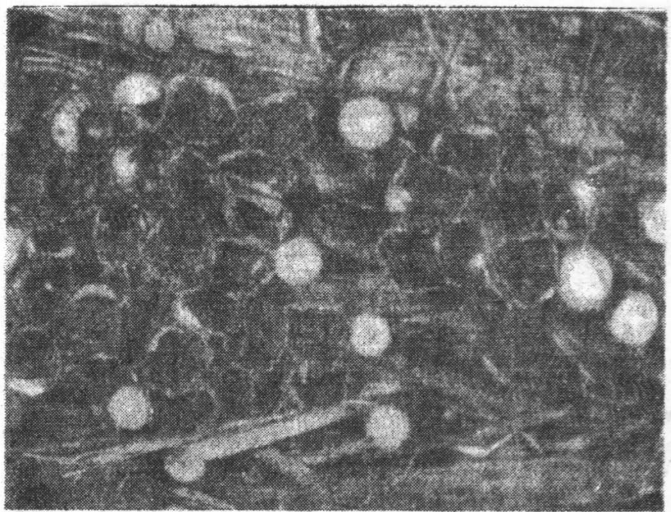

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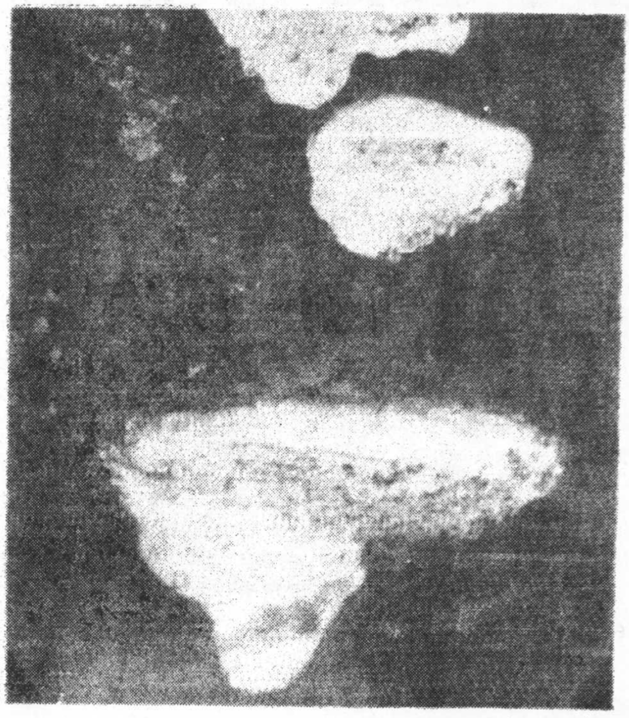

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Plate 6 **(A)** The slime mold *Physarum polycephalum* growing in Acadia National Park, Maine. (From BPS—B. J. Miller) **(B)** The white slime mold *Brefeldia maxima* growing in Acadia National Park, Maine. (From BPS—B. J. Miller) **(C)** Yellow morel *Morchella esculenta*, family Morchellaceae, from Prince William Forest Park, Virginia. (From BPS—B. J. Miller) **(D)** "Splash cup" bird's nest fungi (*Cyathus striatus*); when raindrops strike the fungus, spores splash out of the sup shaped fruiting body. (From BPS—B. J. Miller) **(E)** The fungus *Ischnoderma resinosum* growing in Acadia National Park, Maine. (From BPS—B. J. Miller)

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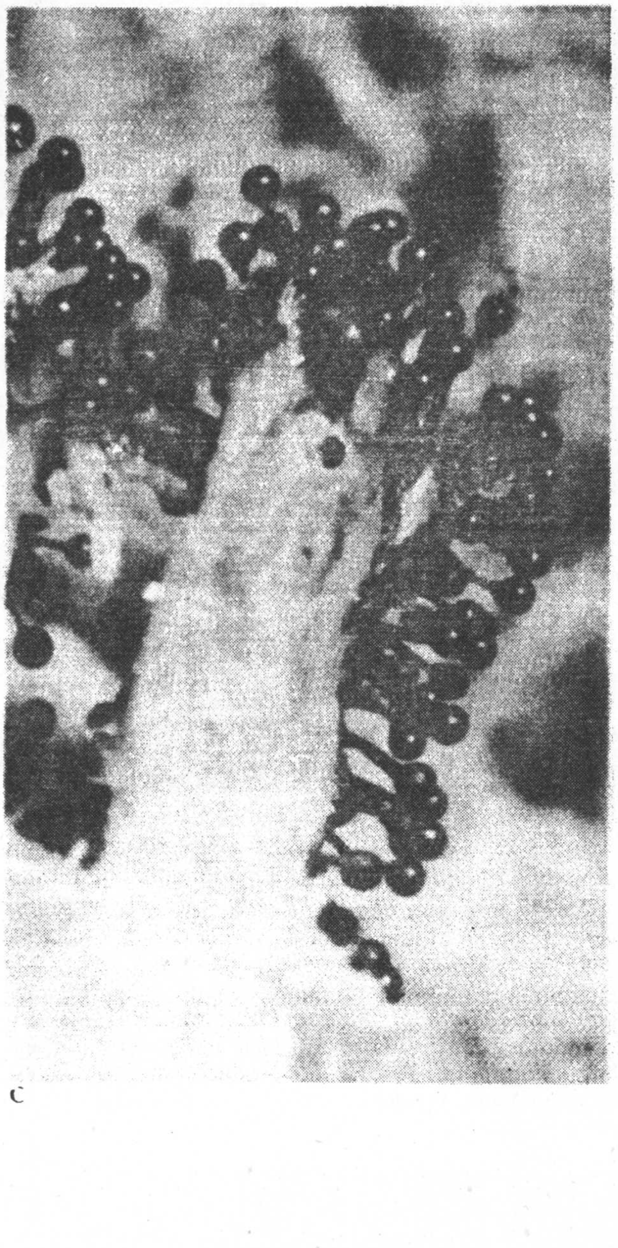

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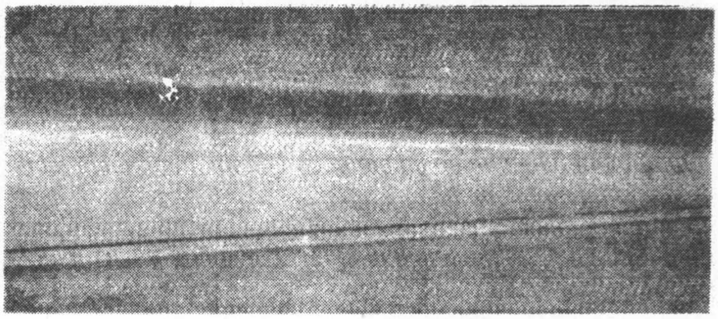

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Plate 7 Microorganisms live in diverse and sometimes extreme habitats.) **(A)** Microorganisms growing in the outflows of hot springs in Yellowstone National Park form zones based on temperature tolerances that are clearly visible by the characteristic colors of the microbes. (From BPS—Richard Humbert) **(B)** Iron springs in Banff National Park, Canada, with heavy growth of iron bacteria. (From BPS—R. L. Moore, Bio-Techniques Laboratories) **(C)** Slime mold growing on a fallen log. (From BPS—Richard Humbert) **(D)** The growth of halophilic bacteria and algae in saline lakes, such as Great Salt Lake, Utah, is clearly visible because of the pink color imparted to the water. (Courtesy National Geographic Society—Paul Zahl.)

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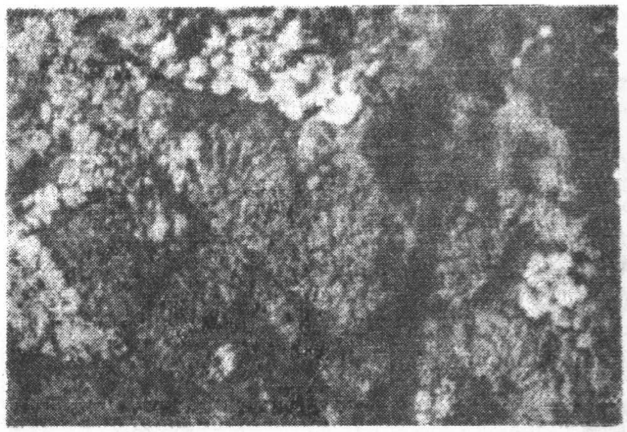

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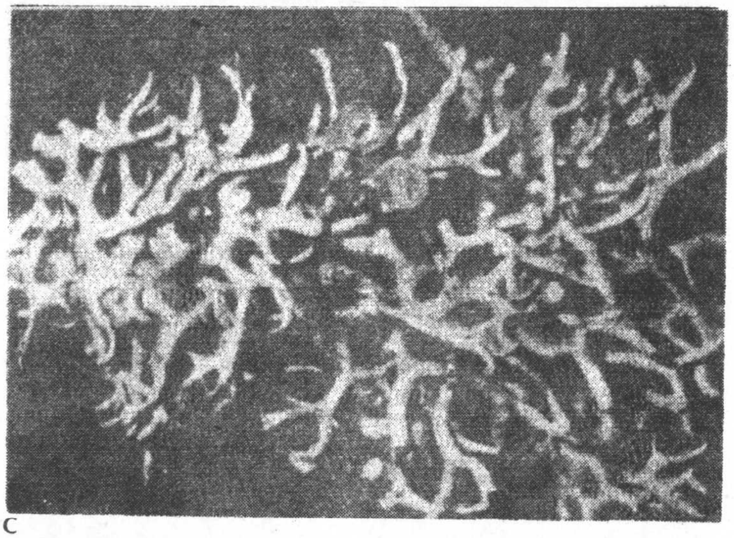

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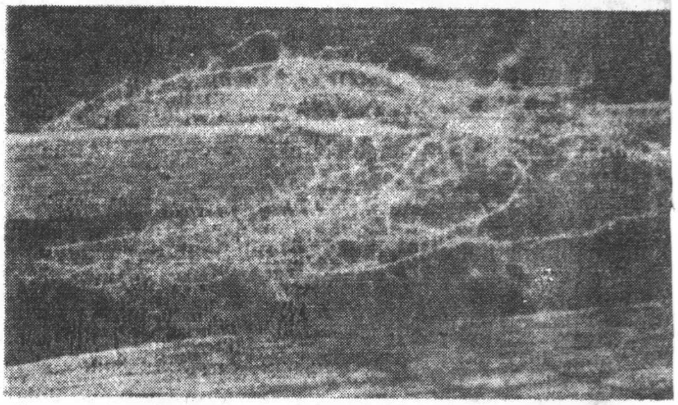

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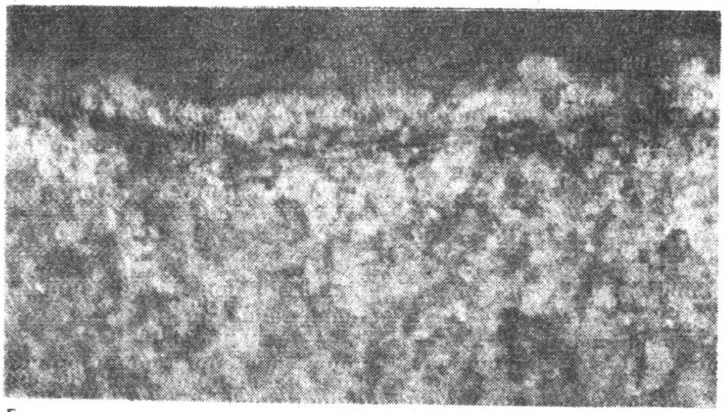

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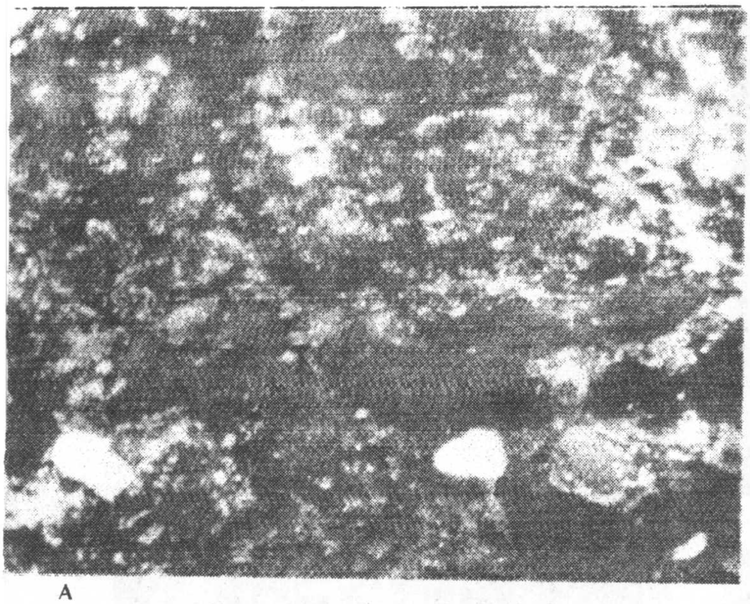
Plate 8 Lichens are formed by the symbiotic (mutualistic) association between a fungus and either a cyanobacterial or algal photosynthetic partner. Lichens grow very slowly, often in very dry habitats. **(A)** Yellow lichens growing on rocks in the Peruvian-Chilean desert. (From BPS—F. J. Ordenaal, Duke University) **(B)** Several crustose lichens growing on a rock surface. (From BPS—J. N. A. Lott, MacMaster University) **(C)** A foliose lichen (*Hypogymnia* sp.) growing in Paortola State Park, California. (From BPS—Richard Humbert) **(D)** A fruticose lichen (*Usnea* sp.) growing on a fence rail on the Island of Jamaica. (From BPS—B. J. Miller) **(E)** Endolithic lichens growing within rocks in the dry valleys of Antarctica; the black, white, and green zones represent differentiated parts of the organized lichen thallus. (Courtesy E. I. Friedman, Florida State University, reprinted by permission of AAAS from *Science* 215:1045) **(F)** Lichens often grow only on one side of a tree, depending on the prevalent wind direction. The symbiotic lichen association is very sensitive to air pollutants and, therefore, lichens have disappeared from urban areas due to poor air quality. (Courtesy Varley Wiedeman, University of Louisville)



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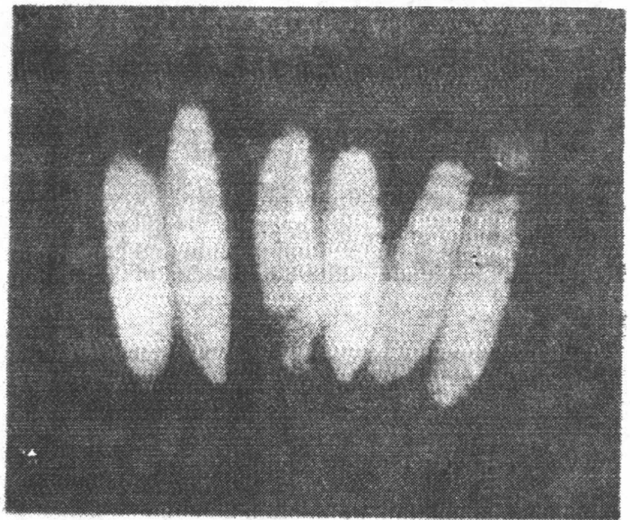

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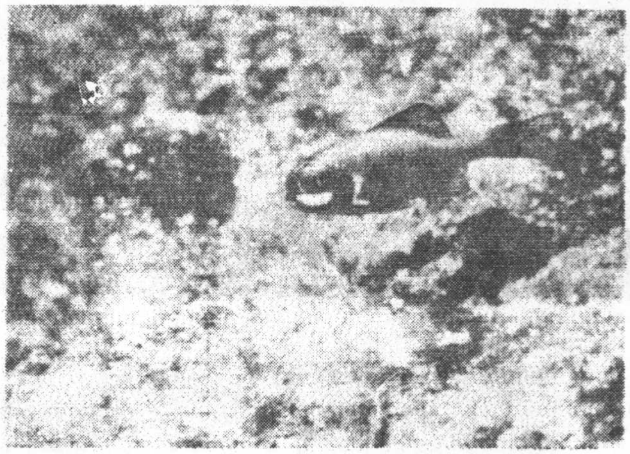

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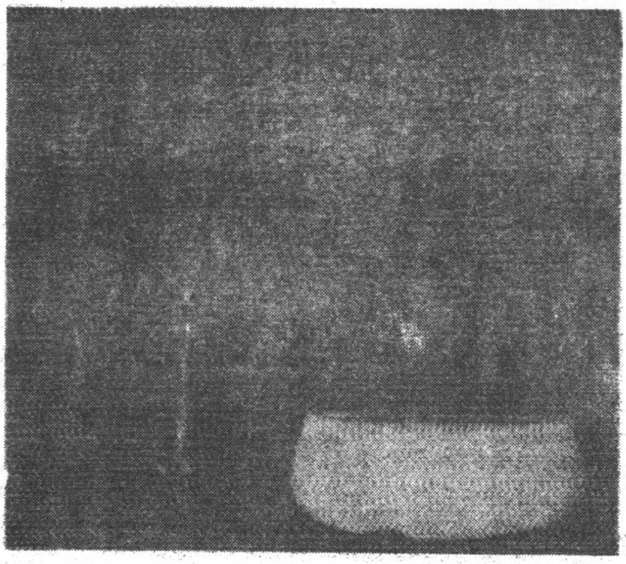

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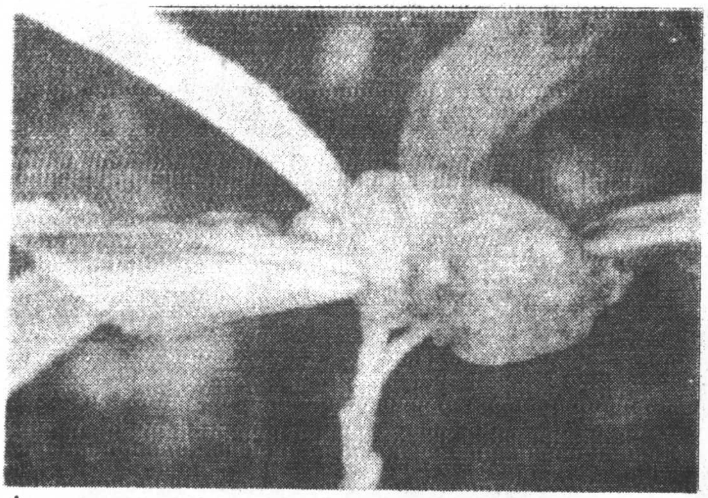
Plate 9 Animals establish various symbiotic relationships with microorganisms. **(A)** *Prochloron* symbionts of a small colonial tunicate from Heron Island, Great Barrier Reef, Australia, impart a green color to the animal. (From BPS—J. Robert Waaland, University of Washington) **(B)** This anemone has a green color because of symbiotic yellow–green algae (zoochlorellae). (From BPS—J. Robert Waaland, University of Washington) **(C)** Caterpillars (*Galleria melonella*) infected with a nematode (*Heteroghabditis bacteriophora*) containing the luminescent bacterium *Xenorhabdus luminescens*. (From BPS—Gerard Thomas, University of California, Berkeley) **(D)** Flashlight fish (*Photoblepharon palebratus*) from Comorro Island, Indian Ocean, have luminescent bacteria growing in specialized organelles near the eyes that provide light in the depths where the fish live. (From BPS—David Powell, Monterey Bay Aquarium) **(E)** Photograph of two agar slants and a broth culture in a flask taken by the light given off by the luminescent bacterium *Photobacterium phosphoreum*. (From BPS—Paul Johnson, University of Rhode Island)



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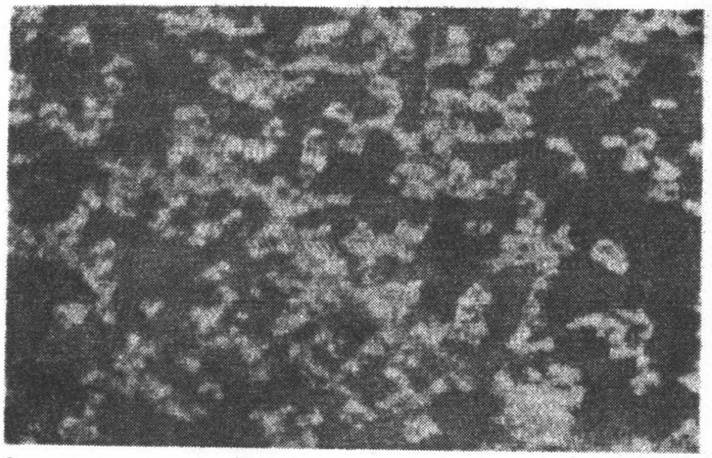

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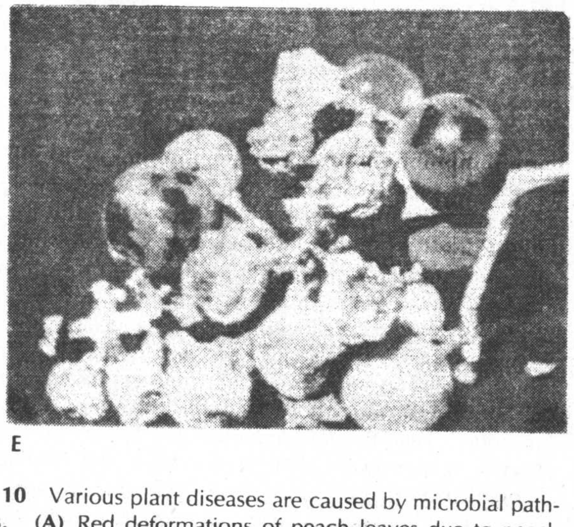

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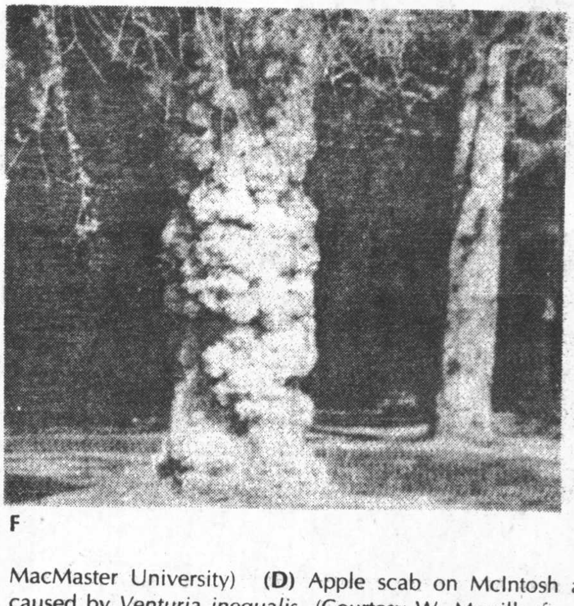

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Plate 10 Various plant diseases are caused by microbial pathogens. **(A)** Red deformations of peach leaves due to peach leaf curl caused by the plant pathogenic fungus *Taphrina deformans*. (From BPS—Phil Gates, University of Durham) **(B)** Micrograph of infected leaf showing hyphae and conidiospores of the powdery mildew *Spherotheca*. (From BPS—Phil Gates, University of Durham) **(C)** Lower surface of Lombardy poplar leaf showing release of spores of the fungus (*Melampsora*) that causes poplar rust. (From BPS—J. N. A. Lott, MacMaster University) **(D)** Apple scab on McIntosh apple caused by *Venturia inequalis*. (Courtesy W. Merrill—from the teaching collection of the Department of Plant Pathology, Pennsylvania State University) **(E)** Downy mildew of grapes. (Courtesy W. Merrill, Department of Plant Pathology, Pennsylvania State University) **(F)** Crown gall on a willow tree caused by *Agrobacterium tumefaciens* showing typical tumorous growth. (Courtesy W. Merrill, Department of Plant Pathology, Pennsylvania State University)