

A MANUAL  
OF THE  
PENICILLIA

BY  
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AND  
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## PREFACE

Mycologically, *Penicillium* as the generic name of a group of green molds has been known for one hundred and forty years. Studies in this group were mainly floristic up to 1890. Green molds were everywhere and names for them appeared in every enumeration of the fungi of a particular locality, or of the species encountered in the study of decomposing or fermenting substances. Saccardo (1880) followed by Wehmer (1894, 1895) reported *Penicillia* active in the destruction of citrus fruit. Wehmer (1893) reported certain of them to be active producers of citric acid. Johan-Olsen (Sopp) (1898) related them to the cheese industry. The development of culture laboratories during this period made possible their isolation and examination in pure culture; and subsequent physiological studies led to increasing interest in their presence and significance.

Nevertheless, intensive study of the *Penicillia* was limited to less than a dozen laboratories, including those of Wehmer, Bainier, Sopp, Thom, Westling, Biourge, Zaleski, Van Beyma, and Raistrick, until the antibiotic penicillin was brought to America in 1941. Thenceforward, instead of individuals or small groups, hundreds of workers including bacteriologists, pharmacologists, chemists, and chemical engineers, turned their attention to the *Penicillia*. Instead of a casual academic pursuit, the identification of these organisms became a matter of prime biochemical and industrial importance. A restudy of the genus seemed urgent.

Thom's Monograph, *The Penicillia*, was published in 1930. In the intervening years, various new surveys have been made, many new species have been described, and biochemical investigations have directed special attention to many selected species. Finally the development of penicillin shifted the emphasis from single strains, often discussed as species, to the recognition of groups of variants bridging many of the gaps separating strains formerly given varietal or specific rank. Meanwhile, the accumulation of large numbers of strains, representing all of the major groups, made available sufficient material to support a systematic restudy of all of the *Penicillia*.

Upon the establishment of the Northern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, at Peoria, Illinois, the development of a collection of pure cultures of micro-organisms significant to agriculture and industry was undertaken. Raper, who had worked with Thom for the preceding decade, was transferred from the Laboratory in Washington to take charge, and brought with him cultures of all molds from the Thom Collection. Upon the retirement of Thom in 1942, all records and descriptive material ac-

cumulated by him at Storrs, Connecticut, and subsequently in the various laboratories in Washington which came under his direction, were transferred to Peoria. The Collection so established at the Northern Laboratory has been enormously increased during the past eight years by the isolation of new materials from many natural substrates, by the contribution of cultures by many collaborators, and finally through the cooperation of Dr. Johanna Westerdijk who, in 1946, contributed transfers of all of the *Penicillia* in the Centraalbureau at Baarn.

The first obligation of a monographer of the *Penicillia* is to report as truly as possible what his predecessors described under particular names. His ideal is to produce as complete and as faithful a presentation as possible of the work of his predecessors, supplemented by his own observations and knowledge. In contrast to the monographer, the writer of a manual of the *Penicillia* must begin with the establishment of a genus concept, then account for all species that have been assigned to it. He may correct, redescribe, reassign, or reduce to synonymy any specific name and description encountered, *so long as his own descriptions lead to the identification of actual material*, and to the assignment to that material of Latin names which are correct according to accepted rules of nomenclature. His primary obligation is to the investigator who needs to identify an organism. The manual must, in addition, furnish such guides to the literature as will permit the critical worker to search original sources for himself whenever he requires more detailed information than the manual supplies.

With this background and philosophy, the preparation of this Manual was undertaken. The monographic feature of Thom's earlier work (1930) has been dropped. The concept of series, i.e., groups of strains having fairly consistent morphology and usually showing related biochemical activities, is emphasized. Within each series, recognized species are arranged in what we consider to be a logical sequence, and the reasons for their recognition are indicated. The punctilious systematist will find that the description of a species of *Penicillium* is no longer a "photograph-like" presentation of the first strain, or type, as found, but represents instead a composite of characters selected as the result of continued cultivation of many strains. Such a concept is sufficiently broad and elastic to include the usual range of variants which the experienced worker will naturally expect. At the same time, we have attempted to establish species limits with sufficient clarity to exclude forms which are unrelated, and forms which may present only superficial evidence of relationship.

This Manual is designed primarily as a means for identifying *Penicillia* which may be encountered in the laboratory, or which for some reason may be significant in microbiological or biochemical processes. It is

hoped that it will minimize misunderstandings in the interpretation of species as described and understood by our predecessors. In addition, it is intended as a guide by which the investigator may reach the accumulated literature relative to the activities and significance of these molds.

Although the plans for this book had long been tentatively formed, and the materials partially segregated into fascicles, actual preparation followed the suggestion of Dr. W. J. Robbins, then Chairman of the National Science Fund, that help to speed up the completion of the book might be found. In the Spring of 1945 the George F. Baker Charitable Trust Fund made available to the National Science Fund a sum sufficient to provide the services of professional, technical, and clerical personnel necessary to carry out the work. Thereupon, a cooperative agreement was drawn up between the Department of Agriculture and the National Science Fund and work on the project was initiated in June 1945. The cooperation of the Northern Regional Research Laboratory in providing the time of the senior author, in supplying space and equipment, and in performing multitudinous administrative details has been essential to the completion of the task.

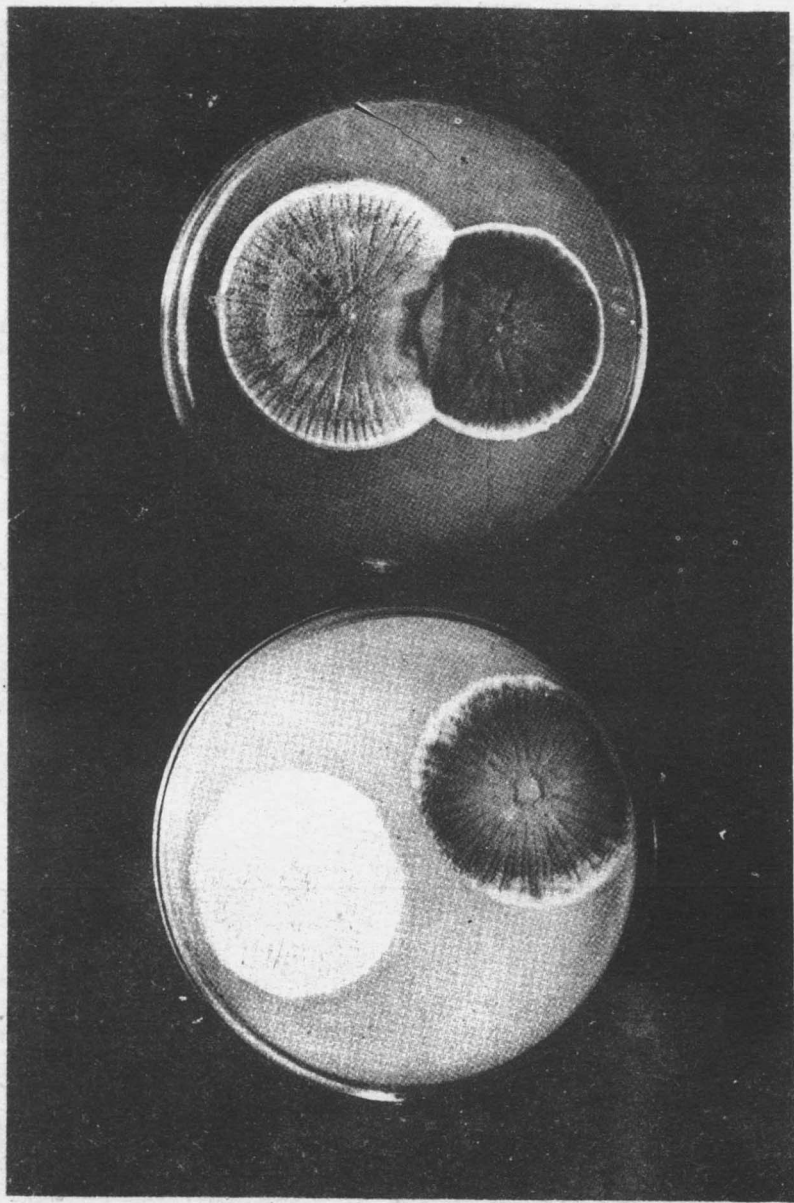
Since fully two thousand strains, in addition to our own original Collection of at least as many more, have been studied, it is impractical to recognize here the contributions of the many workers who cooperated by furnishing cultures. Acknowledgments are made in the text wherever their organisms are discussed.

In the preparation of this manuscript, and in the cultural studies upon which it is largely based, important contributions have been by May H. Flickinger and Jane A. Roberson who made cultures for examination and prepared lyophilized preparations of the strains discussed in the text; by Roland W. Haines and Robert E. Garrett, photographers at the Northern Regional Research Laboratory, who made all of the color pictures as well as the black and white photographs of plate cultures; and by Kathryn E. Dore who typed the manuscript in its final form.

The authors are indebted to the Chas. Pfizer & Co., Inc., Brooklyn, New York, for underwriting the cost of reproducing the natural color photographs.

Administratively, many individuals have contributed to the cooperative project under which this manuscript was prepared. These include W. J. Robbins and Harlow Shapley, Chairmen of the National Science Fund, O. E. May and L. B. Howard, Chiefs of the Bureau of Agricultural Chemistry and Engineering, and H. T. Herrick and G. E. Hilbert, Directors of the Northern Regional Research Laboratory.

THE AUTHORS.



# PLATE I

Natural mutations in species of *Penicillium*

**TOP:** *Penicillium notatum* Westling, showing the normal parent strain, NRRL 832 (dark blue-green colony), and a mutant, NRRL 832.A8, marked by the production of an abundant pink aerial mycelium. Steep agar; 12 days. **BOTTOM:** *Penicillium urticae* Bainier, showing the normal parent strain, NRRL 2159 (light blue-green colony), and a mutant, NRRL 2159.A, characterized by colorless conidia. Czapek's solution agar; 12 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)



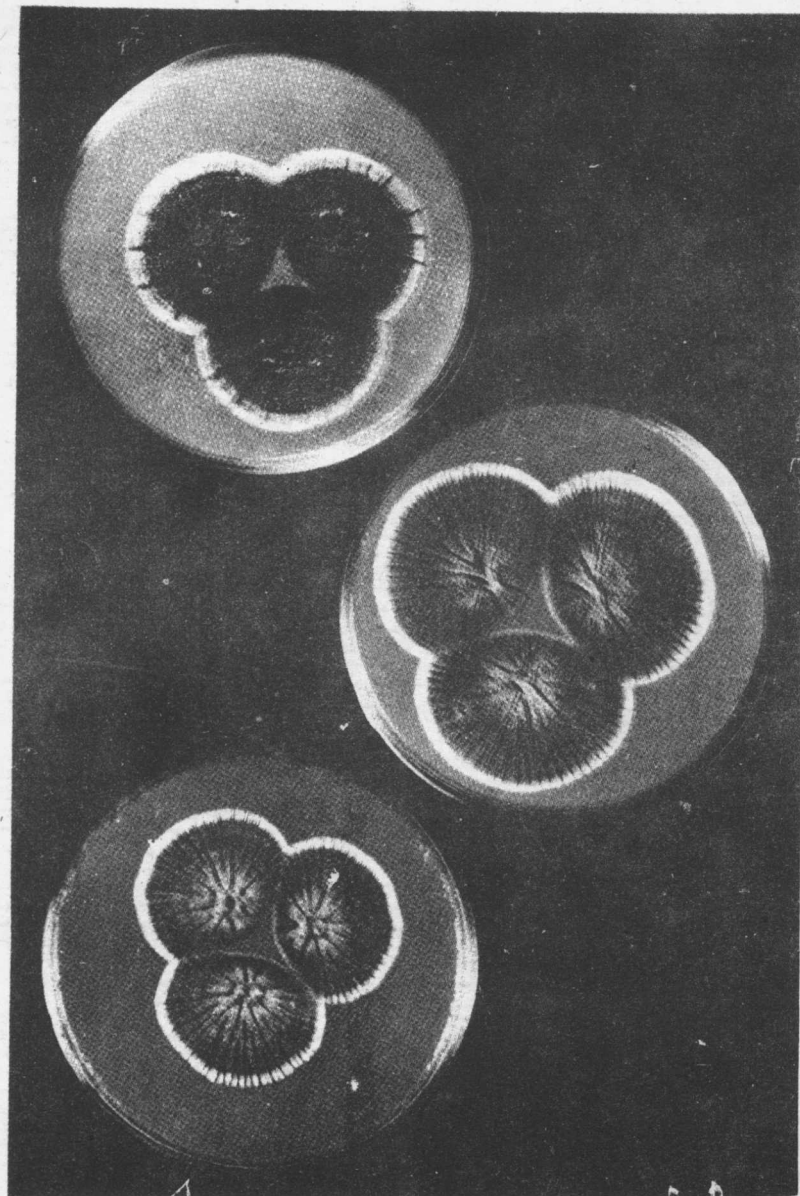


PLATE II

Development of improved penicillin-producing strains in a selected culture of *Penicillium chrysogenum* Thom  
 TOP: Parent strain, NRRL 1951, isolated from a cantaloupe at the Northern Regional Research Laboratory which yields penicillin up to 100u/ml. in submerged culture. CENTER: A natural variant, NRRL 1951.B25, selected at the same Laboratory which yields up to 250u/ml. BOTTOM: An X-ray induced mutation, X-1612, capable of yielding up to 500u/ml.; produced at the Carnegie Institution in Cold Spring Harbor by irradiating conidia of NRRL 1951. B25.

Cultures on steep agar at 12 days. See discussion, p. 96. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)



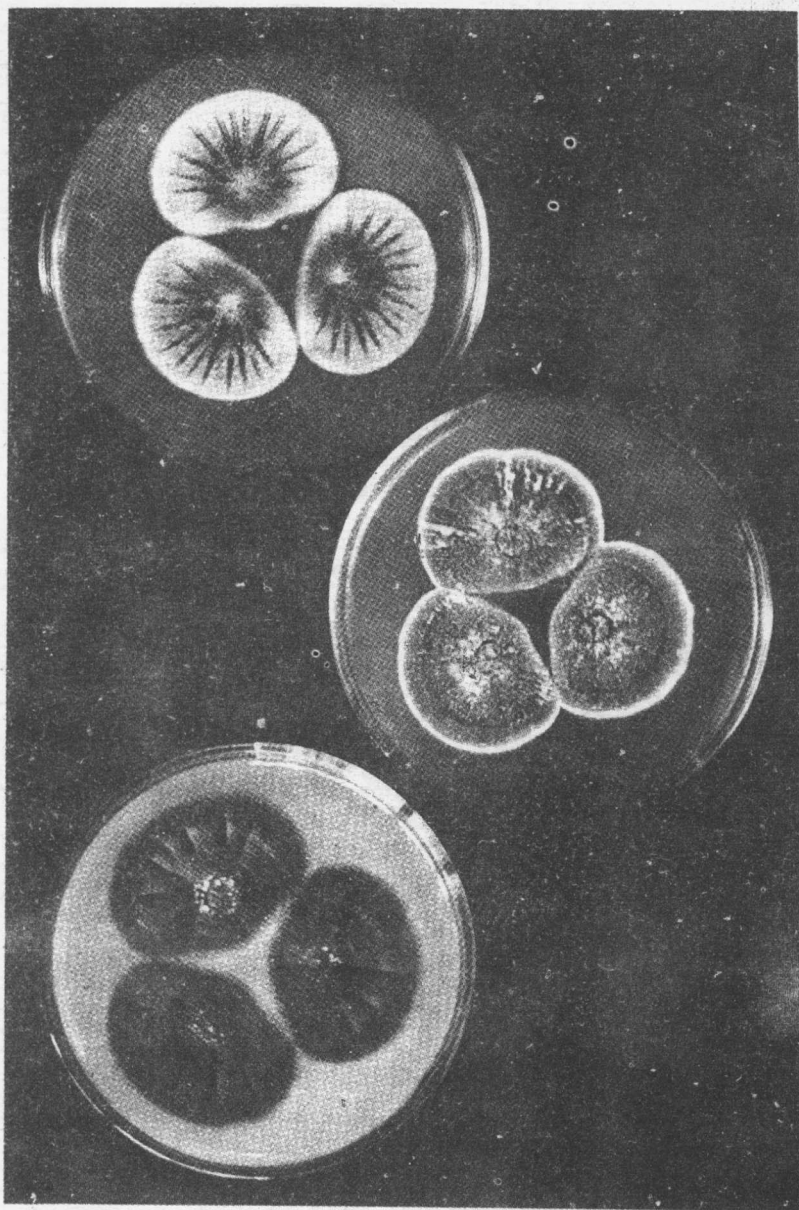


PLATE III

TOP: *Penicillium javanicum* van Beyma, NRRL 707, on Czapek's solution agar, 10 days. CENTER: *Penicillium sclerotiorum* van Beyma, NRRL 2074, on steep agar, 12 days. BOTTOM: *Penicillium frequentans* Westling, NRRL 1915, on Czapek's solution agar, 10 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)

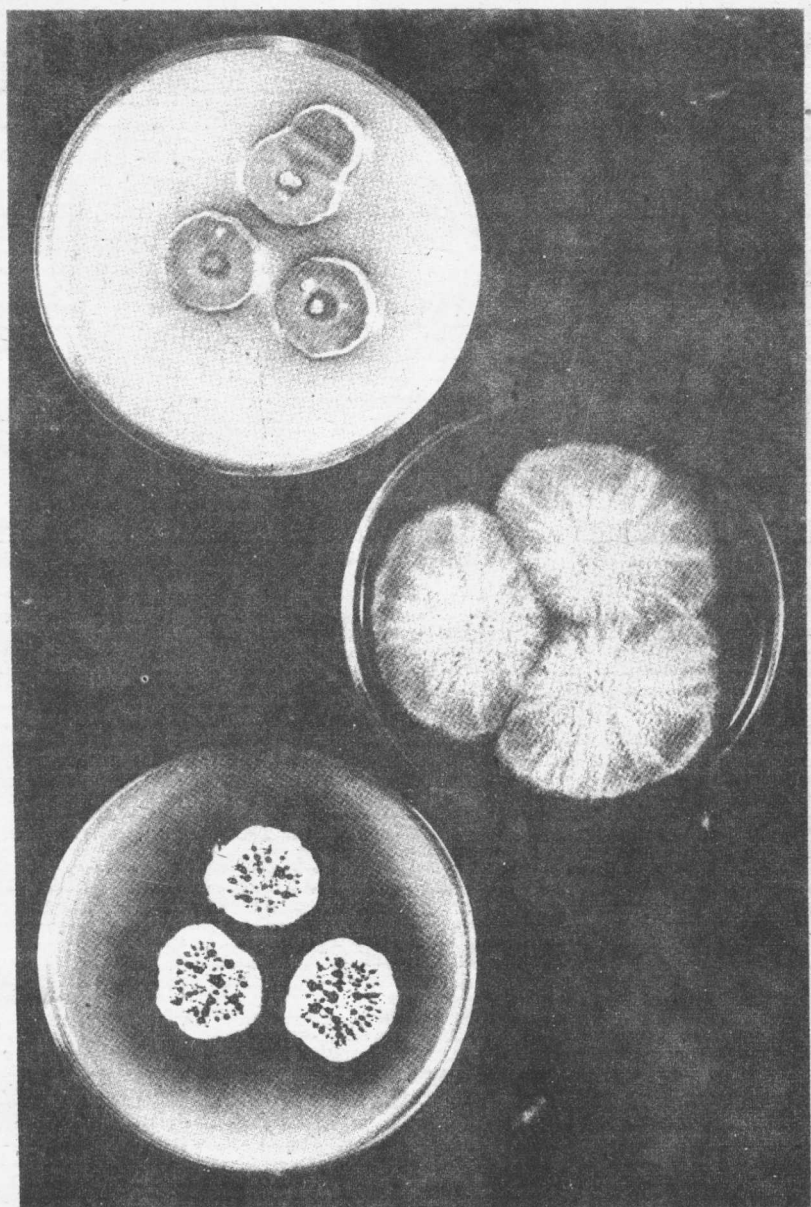


PLATE IV

TOP: *Penicillium mplicatum* Biourge, NRRL 2054, on Czapek's solution agar, 12 days. CENTER: *Penicillium chermisinum* Biourge, NRRL 2049, on malt agar, 10 days. BOTTOM: *Penicillium vinaceum* Gilman and Abbott, NRRL 739, on Czapek's solution agar, 12 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)

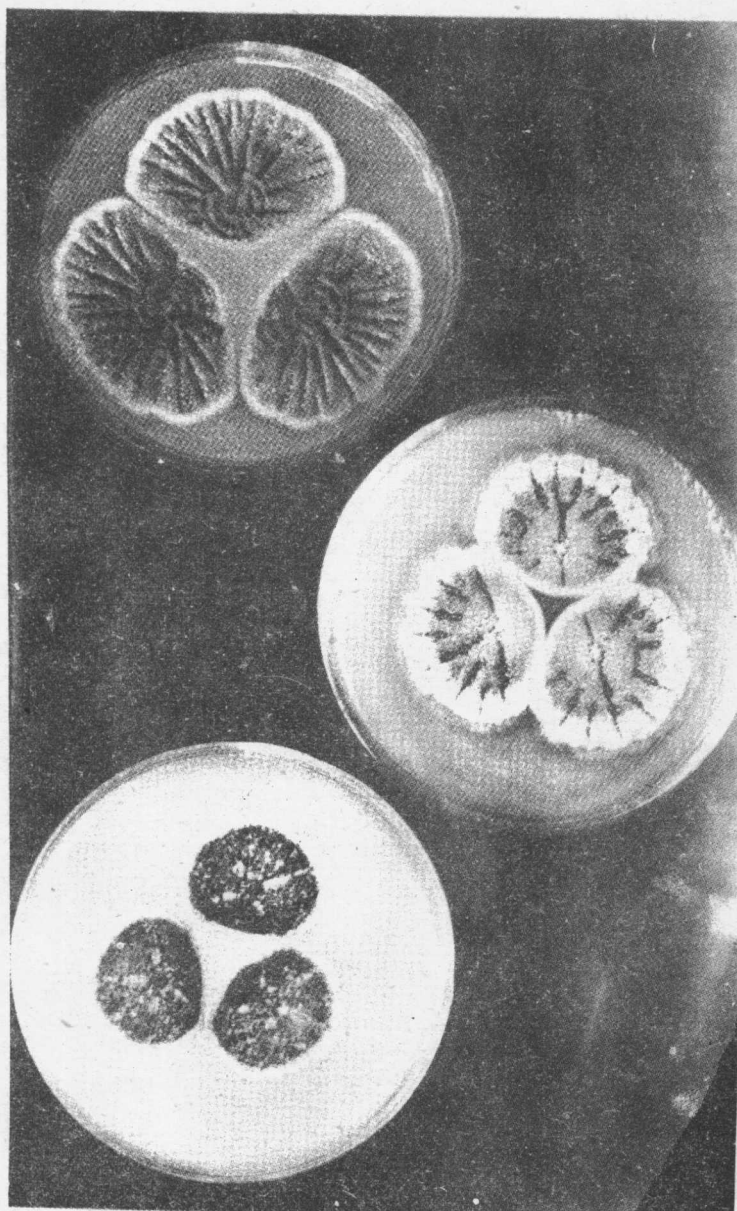


PLATE V

TOP: *Penicillium asperum* (Shear) n. comb. NRRL 2088, on steep agar, 10 days. CENTER: *Penicillium janthinellum* Biourge. NRRL 2016, on Czapek's solution agar, 10 days. BOTTOM: *Penicillium nigricans* (Bainier) Thom, NRRL 915, on Czapek's solution agar, 12 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)

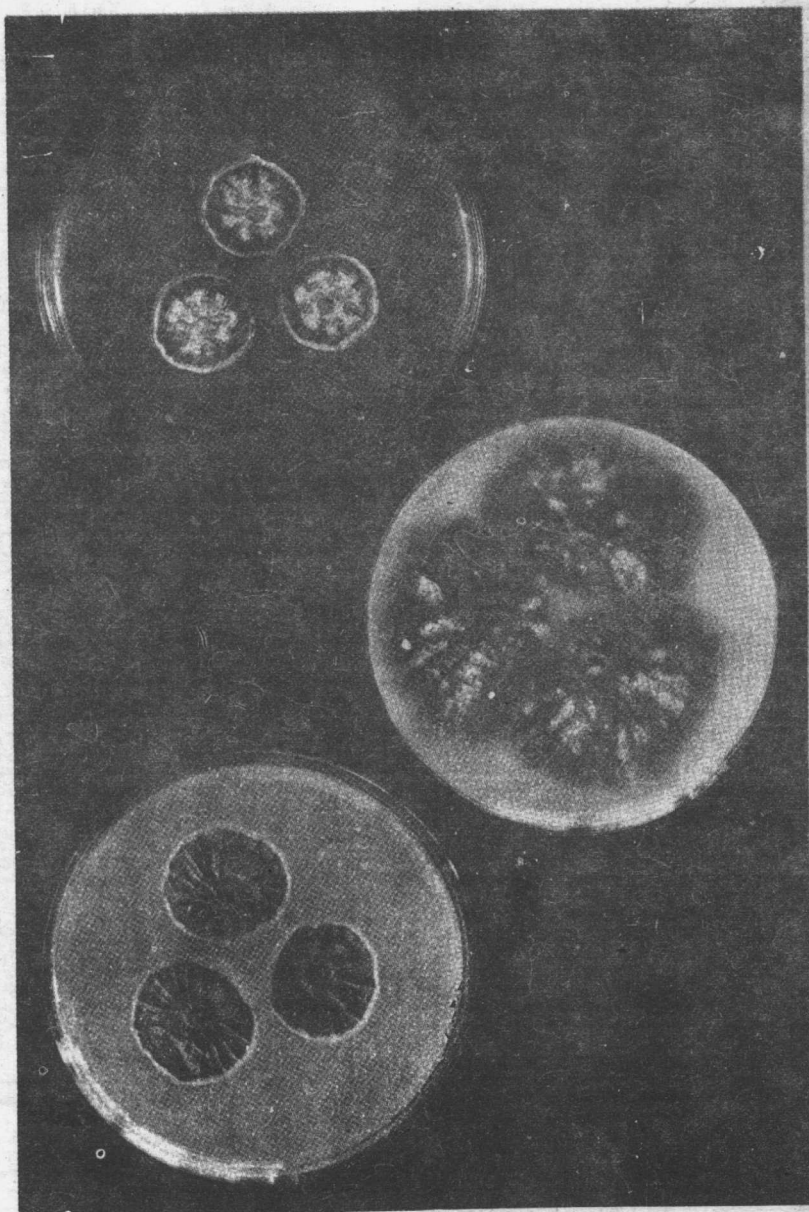
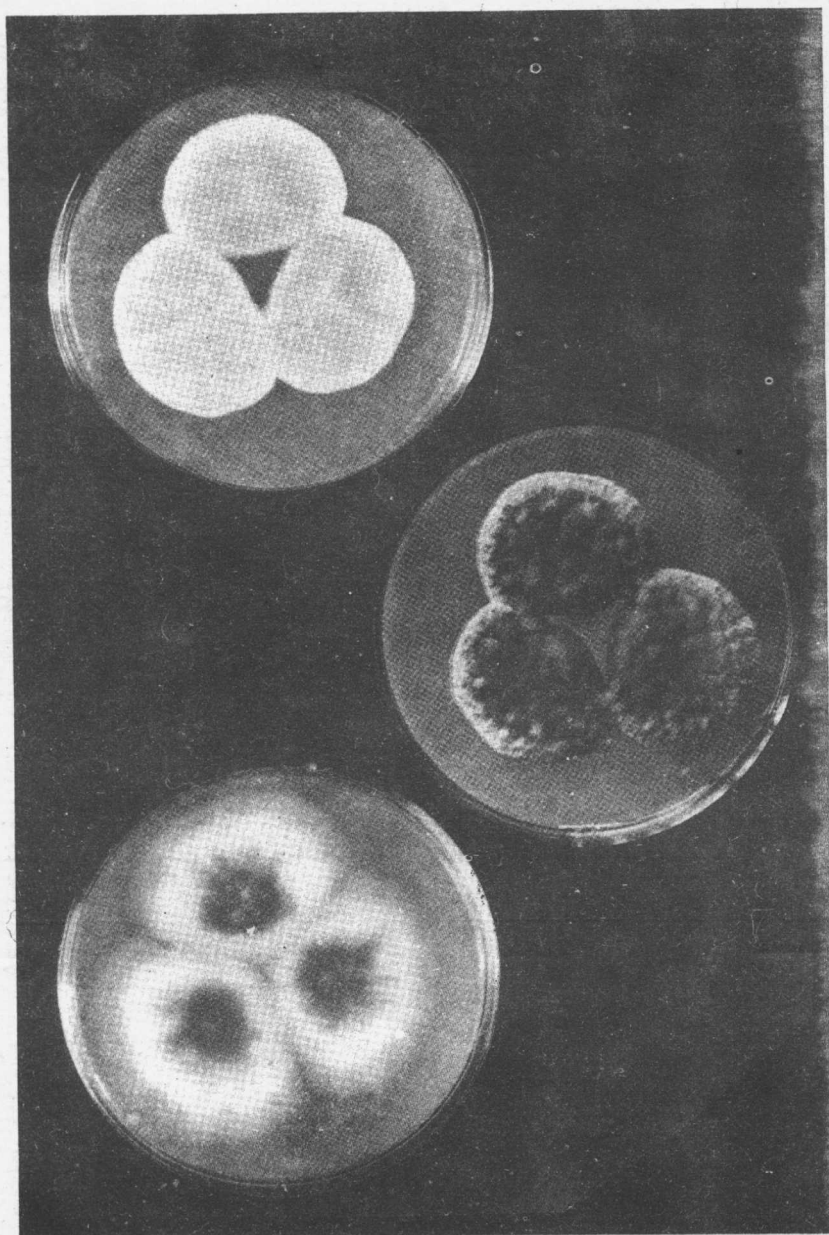


PLATE VI

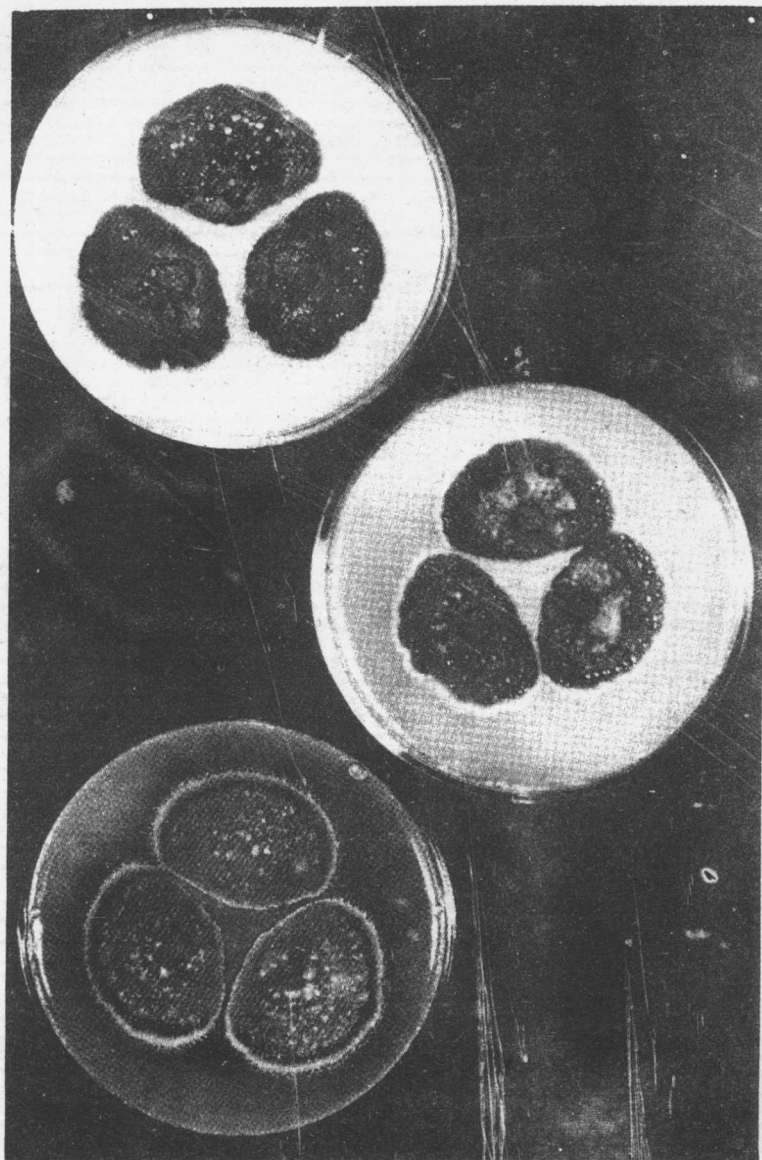
TOP: *Penicillium citrinum* Thom, NRRL 806, on Czapek's solution agar, 12 days. CENTER: *Penicillium roqueforti* Thom, NRRL 849, on Czapek's solution agar, 10 days. BOTTOM: *Penicillium stoloniferum* Thom, NRRL 859, on Czapek's solution agar, 12 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)





# PLATE VII

TOP: *Penicillium camemberti* Thom, NRRL 877, on Czapek's solution agar, 14 days. CENTER: *Penicillium lanoso-coeruleum* Thom, NRRL 888, on Czapek's solution agar, 12 days. BOTTOM: *Penicillium lavendulum* Raper and Fennell, NRRL 2146, on Czapek's solution agar, 10 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)



# PLATE VIII

TOP: *Penicillium viridicatum* Westling, NRRL 963, on Czapek's solution agar, 10 days. CENTER: *Penicillium martensii* Biourge, NRRL 2029, on Czapek's solution agar, 10 days. BOTTOM: *Penicillium corymbiferum* Westling, NRRL 2032, on Czapek's solution agar, 10 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)

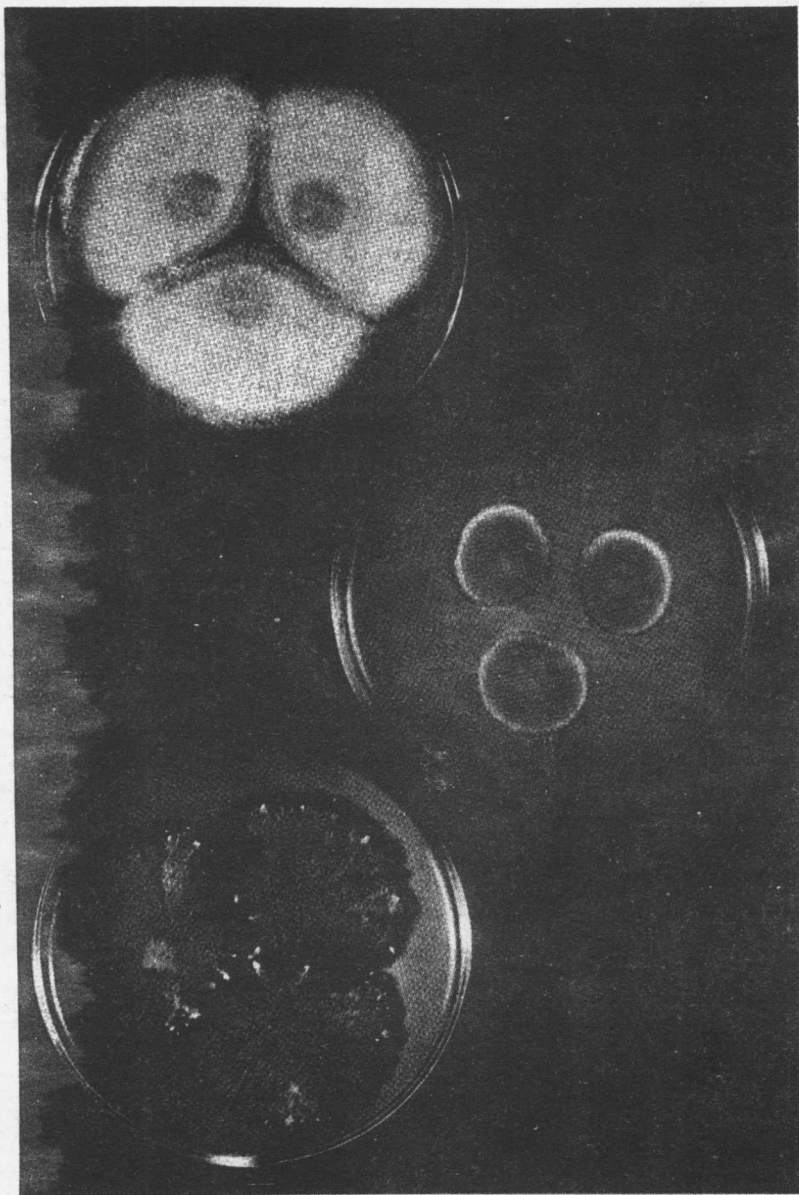


PLATE IX

**TOP:** *Penicillium vermiculatum* Dangeard, NRRL 2098, on malt agar, 12 days. **CENTER:** *Penicillium rotundum* Raper and Fennell, NRRL 2107, on malt agar, 14 days. **BOTTOM:** *Penicillium avellaneum* Thom and Turesson, NRRL 1938, on malt agar, 12 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)



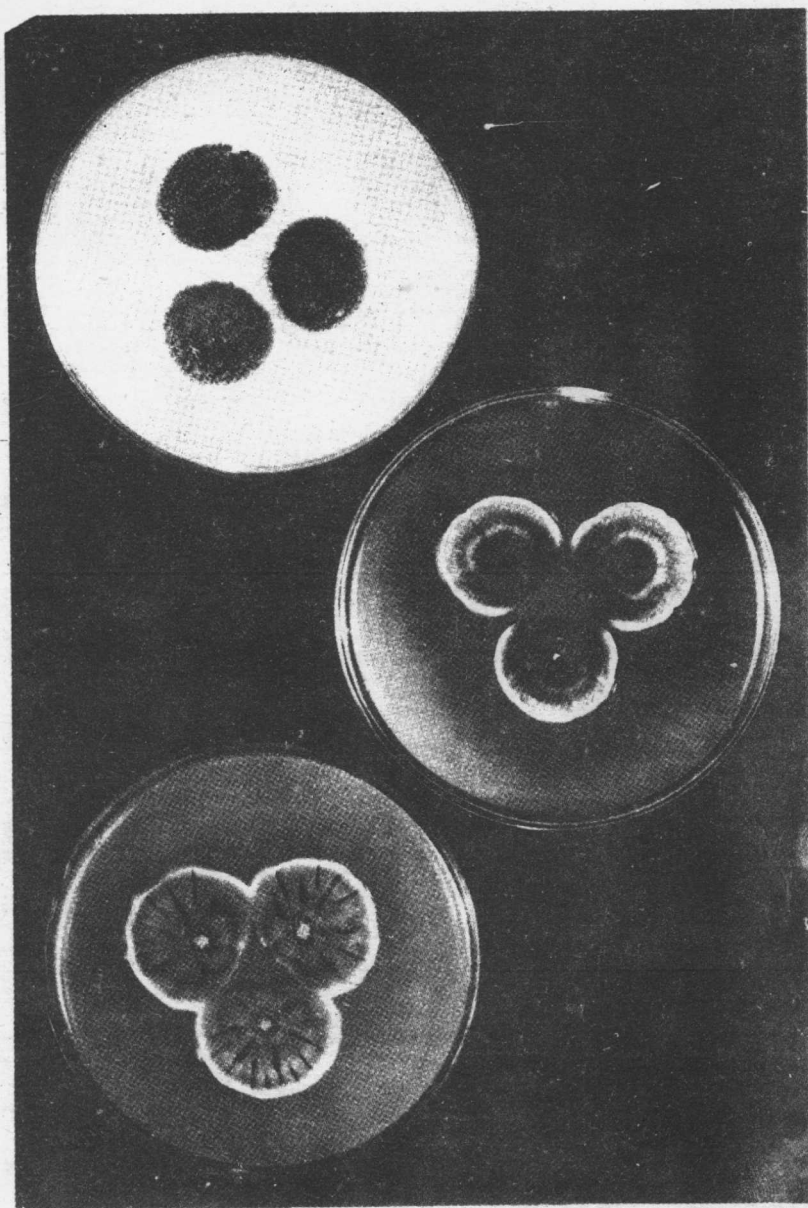


PLATE X

TOP: *Penicillium islandicum* Sopp, NRRL 2115, on Czapek's solution agar, 10 days. CENTER: *Penicillium purpurogenum* Stoll, NRRL 1061, on Czapek's solution agar, 12 days. BOTTOM: *Penicillium herquei* Bainier and Sartory, NRRL 1040, on Czapek's solution agar, 10 days. (Color photographs by Haines, Northern Regional Research Laboratory. Reproduced through co-operation of Chas. Pfizer & Co., Inc.)

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