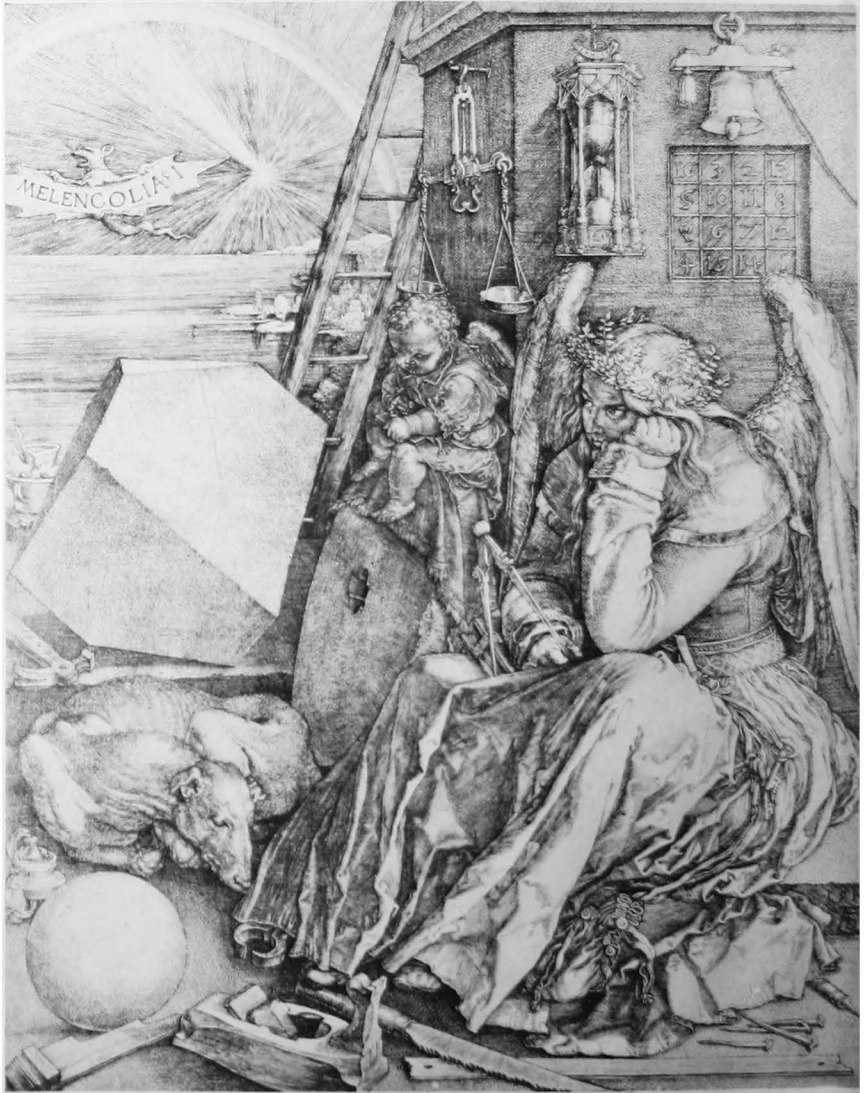


# Science, Servant of Man

### "MELANCOLIA" by Albrecht Dürer (1514)

*This superlative engraving has been chosen as a frontispiece for the book because it expresses the main theme so well and in charming symbols. According to Erwin Panofsky, the mature, learned, and pensive Melancolia "typifies Theoretical Insight which thinks, but cannot act"; while the "ignorant infant, making meaningless scrawls on his slate and almost conveying the impression of blindness, typifies Practical Skill which acts but cannot think." Theory and practice are not "together," but "thoroughly disunited; and the result is impotence and gloom." Displayed strewn about are the tools of science: a sphere and a geometric solid, as well as a magic square (representing mathematics: both geometry and arithmetic), an hourglass for the measurement of time, a pair of dividers for the measurement of space, and a balance. The rainbow and the comet signify the phenomena of nature. The tools of the practical man are likewise in disarray: a block plane, a hammer and nails, a saw, a millstone, and a ladder. The history of our civilization since Dürer's time is in large measure the guidance and direction given to blind Practical Skill by Theoretical Insight, the revolution in the sphere of practical action resulting from scientific thought and experiment.*



*Courtesy of the Fogg Museum of Art*

**ALBRECHT DÜRER'S "MELANCOLIA"**

*(see preceding page)*

SCIENCE,  
SERVANT OF MAN

*A Layman's Primer for the Age of Science*

I. Bernard Cohen

INSTRUCTOR IN THE HISTORY OF SCIENCE  
AND GENERAL EDUCATION, HARVARD UNIVERSITY

*With Illustrations*

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*This book is respectfully dedicated to my  
teachers, from whom I have learned both the  
principles of science and the significance of  
the scientific enterprise: chiefly*

GEORGE SARTON

*and*

George David Birkhoff (†)

Edwin C. Kemble

Otto Oldenberg

*and on a more intimate plane, to:*

PHILIP DAVIS

# Foreword

BY HARLOW SHAPLEY

THE FURIOUS ANTICS of iron atoms in the atmosphere of a star may seem so remote from travel schedules, and the shapes of microscopic animals that have been dead half a billion years so unrelated to the cost of living, that you may be impatient with the labors and technicalities of the astronomer and the geologist. But appearances, and the shopworn jests about impractical professors, have betrayed you. The sun's atoms and the tiny fossils are not remote. The aeronautical companies, as well as the navies of the world, are much concerned with the electronics in solar gases ninety-three million miles away; and the astute businessmen in one of the greatest of industries have invested millions of hard practical dollars in the micro-paleontology of foraminifera in the fossiliferous strata of Paleozoic times. (Please pardon the long technical words, but I use them deliberately to suggest that a quiet academic lane is often the best road to the market place.)

An investment in knowledge of fossils, as shown in Chapter 14 of this volume, aids the development of oil fields, increasing the yield of gasoline, and cutting the cost to the consumer.

The atomic vibrations in the corona of the sun, originally explored just because astronomers wanted to increase their knowledge of the structure of stars, are associated with the radio reflecting layers in the earth's atmosphere (Chapter 16); they are therefore connected with the failures, at times, of those layers to transmit properly the guiding radio signals that make long distance flying safe.

Many such instances of the passage from thought to action, from pure research to its surprising applications, from the quiet, almost aimless explorations in the study and laboratory to the making of entirely new industries and to the creating of new aspects of better

living — many such examples are happily described by Dr. I. Bernard Cohen in the chapters of this book. He tells stories that make one cheerful about the human mind. He describes the ingenuity of the men who turn to important human uses some of the small bits of curiosity-satisfying observation and some of the fragments of logical deduction that come out of the workshop of the free investigator.

The great governments, notably England, Russia, and the United States, have in different degrees recognized that social progress, as well as national safety, will depend in the future more than ever on the degrees to which the people and governments support scientific inquiry and application. There is a growing appreciation of the fact that unhampered basic research is more important than the applications.

Although it appears difficult for some politicians and short-visioned operators in agriculture and industry to see the need of freedom for the investigator to choose his field of study and to follow his own inspiration, that concept is now acknowledged by the government of the United States. The significance to America at this time of basic research is specifically stated in the legislative proposals of the past year or two. But the question *What is the good of it?* frequently obstructs attempts to get generous support for scientific training and research from governmental agencies, and often from industry.

Dr. Cohen, at the request of the National Science Fund of the National Academy of Science, sets out to answer that question in the present volume. He succeeds, and at the same time answers many related questions, such as: *How are discoveries made?* and *What spirit moves the scientist, who sometimes looks for "practical" ends but more often does not?*

It seems to me that the legislators, the government bureau chiefs, the university trustees, and the officials in nearly all large business concerns, could profitably look to the stories here presented of hybrid corn, of electronics, and of the antibiotics that bring new hope for the defeat of human maladies. They might think over the daily experiences of modern life — travel, eating, communications, entertainment, and business activities — and discover that most of them have immediate connections with the work of the little-recognized scientific investigators of the past and with the scientifically trained technicians who make the steps from thought to action.



The epoch of the impoverished, overworked scientists, who struggle in their weary spare hours for the physical and mental welfare of mankind, should be near its end. The people and the governments of the world cannot wisely afford to go without the not-yet-known treasures which deliberate thought and basic research can eventually bring to the civilization.

I shall not be entirely happy about this Foreword unless I return to that phrase, *What is the good of it?* "Good" and "Practical" are words that are too often used loosely as synonyms, and too often given restricted meanings. A research is not good and practical only if it adds to material wealth or physical joys, to new thrills or a longer life. A research is practical also when it provides a thought or a tool that leads to further exploration. A research is practical if it enlarges and enriches the spiritual content of human life and knowledge. The concepts of Newtonian gravitation, of Darwinian evolution, of Mendelian inheritance, of Einsteinian relativity, have indeed provided some noteworthy uses in engineering, plant breeding, and atomic energy utilization; but their greatest human contribution has been in the realms of philosophy, religion, and the social behavior of mankind. In such less tangible fields man transcends his biological environment.

Science is indeed the servant of man, and can do even finer service if fully utilized; but much of its greatness lies in its providing for the meditator as well as for the actor.

## Preface

Science can be interpreted effectively only for those who have more than the usual intelligence and innate curiosity. These will work hard if given the chance and if they find they acquire something by so doing.

— VANNEVAR BUSH (1940)

THE WRITING of this book was undertaken because it deals with what I consider to be one of the most important problems of our age: the relation of scientific discovery to our daily lives and to our well-being and national security. In our day we can no longer afford to be silent partners in the scientific enterprise; we can be intelligent citizens of the scientific age only if we participate to some extent in the scientific enterprise, pervaded by the spirit of science and cognizant of scientific accomplishments. Of course, we cannot all be scientists. But the obligation lies on each of us to understand both the nature of the processes by which science advances and the way in which practical applications of those advances are made to change and expand our world.

Those of us who are not scientists talk of science, or listen to talk of science, in terms of great generalities. We take references to examples which we do not fully understand and toss them back and forth. We accept the description "miracle" of each scientific innovation, although the words "science" and "miracle" belong to totally different activities. Sometimes we turn away from the discovery of a new law of life or law of the universe, or a new phenomenon, because our lack of understanding and experience does not enable us to discern the exciting consequences immanent in the account of it.

Many excellent books are in print that acquaint their readers with the discoveries of modern science, the philosophical significance of

some scientific achievements, the methods of science, and the advances in the practical arts. This is, I believe, the first attempt to study the practical consequences of scientific research by means of selected case histories. I have attempted to describe some of the greatest scientific achievements of our era, showing the steps whereby in each case knowledge grew and developed. By the study of such case histories, drawn from many different fields of research, evidence is brought forth towards certain general conclusions which may be thought of as signposts for our future attitudes and conduct. But the method of case histories has an additional advantage: it gives the reader, vicariously, a measure of the actual experience of those who work in the laboratory to discover new principles, as well as those who put them to use. By this experience, it is hoped that the reader may come to understand not only the significance of the achievements, but also how they came about, and what their relationship is to the economic, cultural, and social implex of which they are a part.

I have had the great privilege of discussing each of the chapters with specialists within whose province each lies. In addition, each chapter was read in manuscript by at least one established authority in that field. In many instances, the critical reader was the very person whose work has been described. As a historian of science, I must admit that this has been a new experience; most history must be written without the aid of the chief characters!

At the end of the book I have acknowledged my indebtedness to the many scientists who have helped me with various portions of the manuscript. But I should like to record special gratitude here to the National Science Fund (National Academy of Sciences), its first chairman, Dr. William J. Robbins, and its secretary, Mr. Howland Sargeant, for their part in suggesting that I undertake this task. Especially to Mr. Sargeant and to Dr. Harlow Shapley, Director of the Harvard Observatory and present chairman of the National Science Fund, am I grateful for continued and extended kindness throughout all stages of the writing of this book. The John F. Milton Fund of Harvard University awarded a grant during the years 1942-1944, but for the aid of which the book could never have been written.

I. BERNARD COHEN

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