genetic code was begun by employing artificial messenger RNA molecules to synthesize proteins in vitro; and Jacob and Monod presented their elegant model that explained gene regulation as the control of the transcription of genic information into messenger RNA. The sense of fundamental progress was so impelling in those days that experimental evidence may not have received the careful critical scrutiny it would have in less exciting circumstances. In view of the extent to which the major tenets of molecular biology have pervaded current thinking and are guiding research on development, behavior, and evolution, a critical consideration of these tenets seems called for.

This slim volume by Henry Harris is a laudably lucid contribution to meet the need. While Harris analyzes a number of issues, including the question of the physical state and stability of the messenger, his most important undertaking is to challenge the idea, given powerful impetus by the Jacob-Monod operon model, that cell differentiation consists in the selective "turning on" or "turning off" of gene transcription. Harris reveals weaknesses in the evidence and arguments that have been presented in favor of this idea, an idea that was based originally on work with bacteria. Studies of eukaryotic microorganisms, particularly the marine alga *Acetabularia*, and hybrid cells of higher organisms provide, on the contrary, impressive support for the view that regulation is a cytoplasmic activity. In these organisms the messengers of the genes are relatively long-lived, and their expression appears to be mediated by events taking place in the cytoplasm. The concept that regulation and cell differentiation in eukaryotes occur in the cytoplasm does not require, however, any revolutionary overthrow of molecular genetics; the basic model of gene action and control can readily assimilate this view. It is possible to imagine, of course, that regulation and differentiation may sometimes occur directly at the gene level, and at other times in the cytoplasm, where protein synthesis is known to take place. With so much attention in developmental and cell biology being devoted these days to chromosome "puffs," heterochromatization, histone inhibition of gene transcription, and other indicators of controlled gene activity, Harris's book serves the useful purpose of warning against premature narrowing of research and neglect of the cytoplasm.

Possibly eukaryotic cells differ from bacteria in the mechanisms by which regulation is achieved. Harris does not think so, for he believes the evidence is not convincing that gene transcription is regulated even in bacteria. In this respect I think Harris overstates his case. Unfortunately, his book was written before the repressors of bacterial beta-galactosidase synthesis and of lambda virus replication were isolated and described in some detail. The properties of these repressors offer persuasive support for the hypothesis that, in bacteria at least, genetic regulation occurs at the level of the gene itself.

The skeptical, critical approach of Harris may put off some readers, but I recommend it as a necessary, if bitter, antidote for the enthusiastic, uncritical reception that the model of gene regulation has received in some laboratories and schools. Few will end their reading of this book without a sober reevaluation of the complexity of cell differentiation and of the molecular evidence on which current views of gene action are based.

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How Weather Has Been Measured

Invention of the Meteorological Instruments. W. E. KNOWLES MIDDLETON. Johns Hopkins Press, Baltimore, 1969. xiv + 370 pp., illus. $12.

Human ingenuity did not begin with the space age. It may surprise many to see just how ingenious the forebears of the contemporary scientist and technician were. It may also comfort and instruct today's researcher to take a backward glance at the hang-ups of his clever predecessors. Knowles Middleton's new book *Invention of the Meteorological Instruments* presents us with both opportunities. His scholarly chronicle, which stops short of the space age (or even the atomic age), leaving that story to, as he puts it, "more knowledgeable pens," takes up in order the development of instruments for measuring atmospheric pressure, temperature, humidity, rain, evaporation, wind, duration of sunshine, upper winds, and height and motion of clouds, and combinations of these instruments in the form of meteorographs. It is rich in original source material and painstaking detective work that took the author to many of the historical scientific centers and libraries of Europe.

Though the book is in no way a treatise on physical principles, one is inclined in reading it to reflect upon them. The question Just what is temperature anyway? will occur to the thoughtful novice as he reads about the uneven, hazard-strewn evolution of thermometers and temperature scales. And the more sophisticated reader may also ponder what his concept of temperature might have been some hundred years ago. The development of the aneroid barometer provides an example of the constraints that his own point in time can put on the instrument-maker. The original idea for this type of barometer preceded its actual construction by 300 years, apparently because of the generally accepted belief that metals were slightly porous.

The names made famous by textbooks appear, but well diluted by a welter of unfamiliar ones. So much work was done by scientists now obscured by the passage of time. The author gives them new and deserved exposure. And some of the well-advertised names pop up in surprising contexts. The inventor of the Wheatstone bridge, familiar to every physics student, is credited with designing an anemometer whose sensor was a suspended sphere. Even names famous outside the sciences appear now and then. For example, Sir Christopher Wren, the renowned 17th-century British architect, designed a number of meteorological instruments, including the first tipping rain gauge.

A serious work, this book still offers whimsy for those who have an eye for it. In reading about the ideas put forth by these imaginative minds of the past one encounters a wide spectrum of alternative solutions to a given problem. Some are bound to be out of the ordinary, enough so to provoke a smile. One type of early hygrometer sensed changes in humidity by utilizing a small vessel made of humidity-sensitive material, which was attached to a glass tube much in the fashion of the bulb of a mercury thermometer. As the vessel expanded and contracted with changing humidity the mercury would fall and rise in the tube. Elegant bulbs of very thin ivory were fashioned for this purpose—no mean feat for the instrument-maker. By way of contrast, David Wilson of Dublin used as the sensing vessel the urinary bladder of a rat. Such was his success that he made hundreds of these hygrometers, and in the process he discovered quite incidentally that "London rats are very subject to urinary calculi which I do not find to be the case in other towns." Middleton allows this may be the result of the rat race.

Another example of sensors selected from our organic environment is the wild oat. The famous Robert Hooke used the beard of an oat as the sensor for a hygrometer. The spiral fiber in the center of the oat twists and untwists with changes in humidity, and it was not difficult for one with Hooke's talents to incorporate it in a successful indicating instrument. One is constantly reminded as the pages go by that there are, so to speak, many ways to skin a cat and an incredible number of them have already been tried. How many more can there be?

It would be inappropriate, even in a short discussion about the invention of meteorological instruments, not to mention those ingenious ancestors of the modern automated weather-observing station, the weather clocks. Christopher Wren and Robert Hooke were very much involved in their early development. A quotation from *Journal Books,* 9 January 1678/9, describes well their function: they were

> . . . made to keep an Account of the Quantity and kind of all the Changes that happen in the Air as to its heat and cold, its dryness and moisture, Its gravity and Levity, Its motions in what Quarter and with what strength and Velocity, As also of the kinds and Quantity of the Rain, Snow and hail that falls all which it sets down in Paper, so as to be very legible and certain.

For about 200 years meteorographs of remarkable complexity were built and installed in observatories and elsewhere. Middleton explains their final demise as follows:

> . . . there were two reasons for this. In the first place it was just beginning to dawn on a few meteorologists that the rapid spatial and temporal fluctuations on the meteorological elements put a limit on the desirable or indeed attainable precision of measurement. The second was the introduction in the 1880's of a series of small, light, and inexpensive recording instruments by the Paris firm of Richard Frères. The great meteorographs, like the huge reptiles of the Jurassic era, simply could not compete.

So the small, efficient meteorograph was born. It is interesting that miniaturization, a hallmark of much contemporary instrumentation, was an accomplished fact in meteorographs before the beginning of this century. The desire to sound the atmosphere with kites and small unmanned balloons provided continuing impetus for this development. And by 1906 W. H. Dines of Great Britain had produced excellent meteorographs (recording temperature and pressure) that weighed only 28 grams.

The book is generously and beautifully illustrated with everything from rough woodcuts to fine engravings. At first glance it might be mistaken for a text on the history of scientific illustration. There are 224 figures, a ratio of two for every three pages.

The story ends with the Second World War, at a point in time where personal recollection begins to serve as makeshift historian for many of us. One can only hope that another "knowledgeable pen" will come along to continue Middleton's scholarly record.

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A 17th-Century Figure

John Wilkins, 1614–1672. An Intellectual Biography. BARBARA J. SHAPIRO. University of California Press, Berkeley, 1969. xii + 336 pp. $9.50.

One of the better ways to approach a complex and remote period is to fasten upon a single, key individual and follow his evolution as a mirror of the times. Bishop John Wilkins (1614–1672) was one of those men at the center of the intellectual currents of the 17th-century scientific revolution whose lives repay careful consideration in this light. Anthony à Wood, a contemporary biographer, reported that Wilkins "was a Person endowed with rare gifts," being "a noted Theologist . . . an excellent Mathematician and Experimentist," as well as one well versed in astronomy, mechanics, and the new philosophy "of which he was [as] great [a] Promoter as any of his time."

Barbara J. Shapiro has undertaken the difficult task of attempting to synthesize the varied interests of this ingenious and industrious man. She has succeeded in putting together, in a highly professional way, a coherent and well-written account of Wilkins's intellectual activities and relations with his contemporaries. In structure, the book presents few surprises: it recounts (briefly) Wilkins's early life, his early scientific writings, his years as Warden of Wadham College, Oxford, and the prehistory and early years of his Royal Society career and, finally, records Wilkins's last views on science and religion.

Shapiro is, however, after bigger game than this brief outline implies. She is aiming at no less than the resolution of a knotty debate that has been troubling historians of science for a generation. In the 1930's the sociologist Robert K. Merton advanced the view (similar to the Weber-Tawney thesis) that puritanism and its ethic were intimately connected with the rise of science in England and elsewhere. Since that time the debate has flared intermittently and appears only now to be exiting, not so much solved as agreed to be insoluble. Shapiro offers a different "science and religion" view, that moderate religion (latitudinarianism) and not puritanism is the key that opens doors to the understanding of the origins of modern science. The case made is a good one—even a moderately convincing one. It suffers (and benefits) from the same disability as the puritanism thesis: the definitions of "puritan" and "moderate" remain too diffuse for close application. The historical connections that must be made for a fully satisfactory argument have yet to be completed.

Shapiro's biography of Wilkins is a solid, conventional one, although it may seem, to some, a trifle pallid compared with such recent scientific biographies as Manuel's *Portrait of Isaac Newton.* For historians of science it may have, moreover, an air of quaintness. With the major exception of the puritanism-and-science issue and a few minor ones, we are transported back to the literature, concerns, and debates of a generation ago. A great deal has happened in the last 10 or 15 years of history-of-science scholarship, and very little of it is reflected here. One small example: Shapiro's view of Wilkins's controversies with Dell and with Webster on university reform in the 1650's might well have been altered had she confronted recent work by P. Rattansi, A. Debus, and others concerning Paracelsianism in England. A