objective bases for a world-wide legal order. These are "found in the traditional cultures of what Maine considered the two significant types of societies. This means that the fundamental bases for a universal law are present in deep-lying, lasting cultural traditions of the world."

It is Dorsey, too, in almost his last sentence, who brings us round the full circle to the thoughts with which this review began, when he writes: "The legal order must be supported in the hearts, minds, and actions of men to be vital." There of course is the crux of the whole problem. There also is the opportunity for men who have confidence in the processes of education and persuasion. And for them this book will prove both an inspiration and a treasure house of ideas and information. All such will agree that Professor Northrop's endeavor and the labors of his galaxy of writers have not been in vain.

Cybernetics: A New Discipline

Churchill Eisenhart, *National Bureau of Standards, Washington, D. C.*

HAVE YOU TAUGHT SOMEONE to drive a car lately? If not, perhaps you can recall how when you yourself were learning to drive, the car, in response to your instructions, veered first too much to the left, then too far to the right, and generally pursued an awkward zigzag course down the road. With training you or your protegé no doubt learned to pilot a car so that it proceeded smoothly, without jerks or wobbles, from one to the other of two given points by what you believed to be the shortest route consistent with the rules of the road and the curves involved. If these remarks bring to mind vivid recollections of the kind of experience just described, then you have already had good firsthand experience with applied cybernetics, and (whether you realize it or not) you already know something about the subject.

The word *cybernetics* is a neo-Greek expression coined to fill a need felt by Professor Wiener[1] and his associates for a single term, unprejudiced by previous usage, that could be used to designate the whole expanse of control and communication theory pertinent to the description, analysis, or construction of systems that involve (1) mechanisms (receptors) for the *reception* of *messages* or stimuli, (2) means (circuits) for *communication* of these to (3) a central *control unit* that responds by *feeding back* through the system (4) *instructions* that (will or tend to) produce *specific actions* on the part of (5) *particular elements* (effectors) of the system. To this end, the word *cybernetics* was therefore formed from the Greek word for *steersman,* $\chi\upsilon\beta\epsilon\rho\nu\acute{\eta}\tau\eta\xi$ (kybernetes). Besides having approximately the desired connotation, this Greek word is all the more symbolic on account of the fact that its Latin corruption, *gubernator,* is the origin of our word *governor,* and, Professor Wiener points out, the first significant paper on feedback mechanisms is the article published by Clerk Maxwell in 1868 on the theory of the purely mechanical feedback system represented by the governor of a steam engine, a device invented by James Watt to regulate the velocity of his steam engine under varying conditions of load.

The central concept in cybernetics is a feedback mechanism that, in response to information (stimuli, messages) received through the system, feeds back to the system instructions that modify or otherwise alter the performance of the system. It is important in cybernetics to distinguish *positive feedback,* which serves to increase what the system is doing in magnitude or direction, from *negative feedback,* which serves to oppose the performance of the system, e.g., to reduce its magnitude or change its direction. Thus, in psychology and neurophysiology one distinguishes between situations wherein an organism responds to a stimulus in such a manner as to acquire an increased amount of the stimulus (*adience*), and situations wherein the response is such as to reduce the amount of the stimulus received (*avoidance*). In practical affairs, positive feedback is generally scrupulously avoided, since, if uninhibited, it will lead obviously to an extreme state. Two cases of positive feedback in moderation that come to the reviewer's mind are (a) adience of young mammals, which is essential to proper receipt of nourishment and to keeping warm; and (b) the regenerative circuits used in radio receivers in the early days, to regenerate and thereby intensify a weak signal. Negative feedback mechanisms, on the other hand, are used widely, and are of considerable interest, for they embody what is generally implied by the word "control."

As we have noted, the governor of a steam engine is an example of a purely mechanical (negative) feed-

[1] *Cybernetics: or control and communication in the animal and the machine.* Norbert Wiener. New York: John Wiley; Paris, France: Hermann et Cie, 1948. Pp. 194. $3.00.

back mechanism. In the original form designed by Watt, two balls attached to pendulum rods swing on opposite sides of a rotating shaft, and their position, via a mechanical linkage attached to a collar about the shaft, controls the opening of the steam valve, reducing the opening when the balls rise (increasing speed), and widening the opening when the balls fall (decreasing speed). Since the balls are thrown outward and upward by centrifugal force (the magnitude of which depends directly upon the angular velocity of the shaft and ultimately upon the amount of steam admitted through the valve) and are pulled down by their own weight, the system seeks a compromise state which with good design is achieved promptly and is preserved. In consequence the engine operates uniformly at the prescribed speed unless the load is changed, calling for more or less steam, which adjustment the balls promptly achieve. Bad design of the governing mechanism, on the other hand, may send the valve into violent oscillation and cause the engine to behave much like an automobile in the hands of a beginner who treads too heavily upon the gas, causing the car to lurch ahead, so that he releases the pressure of his foot upon the throttle, whereupon the car slows up abruptly and he increases pressure upon the throttle and produces another lurch ahead, and so forth.

The ordinary thermostat by which the heating of a house or a room is regulated is perhaps a more familiar example of a negative feedback system. More commonplace, but probably least familiar of all, is the nervous system, which contains a control mechanism that makes possible the performance of our voluntary actions. With training and experience a child can pick up a pencil, cigarette, or piece of candy, without awkward gropings; but if the control mechanism in the cerebellum is in poor adjustment, as in the infant, considerable "hunting" takes place before the hand finds the object; and if the mechanism is damaged by injury to the cerebellum, attempts to pick up an object may (probably will) send the arm into violent oscillations of *cerebellar* or *purpose tremor.*

Although *feedback* (and the *control* over a mechanism thereby effected) constitutes the central theme of cybernetics, there can be no feedback and no control unless there is communication of the incoming message (stimulus) from the receptor to the feedback mechanism and transmission of its message (instructions) to the effector parts of the system (e.g. to the valves of a machine, or to the muscles of an animal). The theory and techniques of *communication* are, therefore, fundamental parts of cybernetics. Since communication of a message may be represented quite generally as a times series of impulses, this brings in the study of *time series,* and especially the statistics of time series, in view of the problem of separating the message carried by a series of impulses from the random "noise" mixed in with the basic signal. Consequently, the theory of wave filters and other devices used in telephone, radio, and television circuits for unscrambling messages from mixed series falls within the province of cybernetics, as does also the theory of fire control devices for directing gunfire. These latter must resolve the true course of a target from the mixed and often contradictory impressions received (as a result of observational errors arising from turbulence of the atmosphere, if the sighting is optical; from static, if radar is used) and compute a predicted position at which to direct the shell. Consideration of such automatic fire control equipment for directing gunfire leads naturally to consideration of automatic sequence-controlled electronic and mechanical computing machines. The analogies of such systems to the brain and the nervous system are tempting.

In *Cybernetics,* the first volume of a projected series, the author has undertaken to survey the entire field of control and communication theory and its various ramifications. He has been remarkably successful in pointing out the similarities and equivalences (from a mathematical viewpoint) of many diverse phenomena of man, animal, machine, and society; and has thus achieved a certain unified approach to problems "of vital importance to psychologists, physiologists, electrical engineers, radio engineers, sociologists, philosophers, mathematicians, anthropologists, psychiatrists, and physicists." To this impressive list might be added also astronomers, geologists, meteorologists, geneticists, and others. Later volumes are to cover specific applications in detail. (A second volume, *Extrapolation, interpolation and smoothing of stationary time series, with engineering applications,* by the same author, is scheduled for publication in June 1949.) The present volume exhibits the value of cybernetics as an analogical tool; its sequels are to demonstrate the power of the method in particular contexts.

In approaching the present volume, the reader should not be discouraged by the mathematical discussions, and should attend more to the spirit of the mathematics than to its detail. Fortunately, the essential ideas are amply expounded in the verbal text; so that on first reading, at least, one can profitably read along at a good pace, omitting the more troublesome mathematical portions. The tremendous scope of this book is evidenced by its chapter headings: (I) Newtonian and Bergsonian Time; (II) Groups and Statistical Mechanics; (III) Time Series, Information, and Communication; (IV) Feedback and Oscillation; (V) Computing Machines and the Nervous

System; (VI) Gestalt and Universals; (VII) Cybernetics and Psychopathology; (VIII) Information, Language, and Society. A panoramic view of the whole is given in the 33-page introduction, which ends with a pessimistic view of the future of human society and a note of discouragement concerning the possibility of developing an exact science of economics or sociology. The reader who is neither a mathematician nor an engineer may profitably skip from the introduction to Chapter IV, on first reading. Chapters II–IV are of particular interest to the mathematician and the electronic engineer; and Chapter III is of interest to the student of theoretical statistics, in view of its new approach to the notion of the amount of information in a series of data.

The text of the American edition, which appears to be a reproduction of the Paris edition (either by use of the same plates or by photographic means), unfortunately contains a fairly large number of typographical errors. The present volume is also without an index. It is to be hoped that these shortcomings will be rectified in future editions of the present volume and given due consideration in the publication of other volumes of the projected series.

Cosmic Science and the Social Order

Harlow Shapley, *Harvard Observatory*

THE MARIA MITCHELL of a century ago and the Albert Einstein of the present come together naturally in a joint review because along with their concern for sanity in social affairs neither slackened in ardor for knowledge of the universe. Maria Mitchell followed well-established lines in her astronomical work, but broke new ground in advocacy of higher education for women. Einstein broke new ground in the interpretation of the universe, then joined the hard fight for the lives and rights of free men.

The books under review[1] are the story of the life and work of a New England spinster of the middle of the 19th century, and the story of a portion of the deep and revolutionary thought of a master mind of this first half of the 20th century. Both volumes are readable and thought provoking.

In her volume, *Sweeper in the sky,* Miss Helen Wright has completed a study to which she has devoted many years. Herself a former student of astronomy in Vassar College, where Maria Mitchell, 80 years ago, spent some of the most fruitful years of her life, Miss Wright explored most thoroughly the earlier career of this outstanding woman scientist—this native of historic and romantic Nantucket Island, where her banker-scientist father guided her early astronomical studies and explorations. The Nantucket of those days was something of a cultural center, visited by the famous poets, writers, and scientists, and the Mitchells did much to make the local culture.

Sweeper in the sky is a volume of charm and unusual interest, largely because it deals with significant phases of mid-19th-century America. The lives and principles of the orthodox Quakers of Nantucket, and

the young girl scientist's gradual, struggling withdrawal from the credal inflexibility of that religious group, make a fascinating tale.

From being a quiet, intense observer of the stars, Maria Mitchell rose suddenly to international fame through the discovery of a comet in 1847. The comet soon disappeared, but her fame remained. She was

[1] *Sweeper in the sky.* Helen Wright. New York: Macmillan, 1949. Pp. vii + 254. $4.00.

The universe and Dr. Einstein. Lincoln Barnett. New York: William Sloane, 1948. Pp. 127. $2.50.