Chapter 2

Introduction and Overview

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A factory whistle blows and the workers leave their stations, punch the clock, and file out into the morning light. The graveyard shift is over. In a scene that is repeated across the country every day, these workers head home to face their nighttime, a nighttime that is at odds with the rest of society and the worker's own internal clock. This is shift work, and whether it involves a factory worker, a waitress at an all-night diner, or an interstate truck driver, this kind of scheduling can produce deleterious effects on the worker and the public.

Shift work, including any permanent schedule of extended duty hours, is an example of how the body's internal clock can be upset by external factors. Another common example is jet lag, the malaise associated with travel across time zones. In the case of jet lag, the effect is short-lived and the body readjusts relatively quickly. In the workplace, however, disturbances of the body clock can continue unabated, and other factors, such as loss of sleep and social disruption, can rapidly come into play to compound the effects. For some workers, when this occurs the results can be deleterious consequences for their health and ability to perform their jobs, which in turn can have detrimental effects on their safety and that of society as a whole.

This provokes several questions: What is the body's internal clock, what is its purpose, and how does it work? For individuals and society as a whole, how does shift work affect productivity, health, and safety? Depending on the answer to the last question, what should be done to lessen the detrimental effects of shift work?

THE BODY CLOCK

One of the most predictable features of life on Earth is exposure to the rhythmic environmental changes caused by the planet's movements. As described by one scientist, ". . . the rotation of the Earth on its polar axis gives rise to the dominant cycle of the day and night; the revolutions of the Earth around the Sun give rise to the unfailing procession of the seasons; and the more complicated movements of the Moon in relation to the Earth and the Sun give rise to the lunar month and to the tidal cycles" (7). Given the pervasiveness of these rhythms, it is not surprising to find that most organisms show alterations in their bodily processes and their behavior in response to them. These cycles are called biological rhythms, and the internal biological mechanisms that control them are the body clock (box 2-A).

Biological rhythms provide a temporal framework for an organism's behavioral and physiological functions (7). For example, many flowers open and close at certain times of day or night, and honeybees time their visits to plants to coincide with these cycles. This increases pollination for the plants and the collection of nectar for the bees. The activity of organisms that live along the shoreline is often in synchrony with the ebb and flow of the tide, ensuring that feeding occurs at the optimal time. Certain animals are active and search for food only at night (nocturnal), while some do so only during the day (diurnal). These are just a few examples of the diverse activities and functions guided by the body clock.

What we envision as an internal dock is actually a group of neurons in the brain that control daily rhythms.

SOURCE: R.M. Coleman, Awake *at 3:00 a.m. by Choice or by Chance* *(New York, NY:* W.H. Freeman, 1986).

Box 2-A—Biorhythms Are Not Biological Rhythms

The **scientific** study of the biological rhythms of the body should not be confused with the theory of biorhythms. No evidence exists to support the concept of biorhythms; in fact, scientific data refute their existence. Based on a theory first proposed by the German scientist Wilhelm Fliess in 1897 and popularized in the 1970s, biorhythm theory postulates that three cycles act in a concerted fashion to guide activity: a 23-day cycle that influences physical strength, endurance, energy, and physical confidence; a 28-day cycle that influences feelings, love, cooperation, and irritability; and a 33-day intellectual cycle that influences learning, memory, and creativity. According to biorhythm theory, these three cycles are linked to an individual's birth date and fluctuate in a constant fashion throughout his or her life. Each cycle has a high and a low point. By mapping the high and low points of the respective cycles and how they coincide or diverge, the theory states, performance can be charted, and critical days when performance can be expected to be highest or lowest can be predicted.

Although a theory that provides a system for predicting human behavior and scheduling activities has appeal, none of the contentions of biorhythm theory can be supported. No biological process with such a relationship to the calendar date of birth has ever been identified, nor have any studies attempting to validate biorhythms been able to do so. Thus, for example, attempts to validate the hypotheses using retrospective airplane crash reports and athletic scores have consistently failed. While there clearly are human biological rhythms with cycles that can be measured in days (the menstrual cycle being an example), there is no evidence for the existence of any of the three biorhythms, let alone any predictive interaction, Given its nonfactual basis, biorhythm theory is relegated to the realm of other popular pastimes, such as numerology, that can serve as a source of entertainment but have no substantive or predictive value.

SOURCE: D.C. Honey, C.M. Winget, C.M. DeRoshia, et al., *Effects of Circadian Rhythm Phase Alteration on Physiological and Psychological Variables: Implications to Pilot Performance (Including a Partially Annotated Bibliography),* NASA technical memorandum TM-81277 (Moffet Field, CA: National Aeronautics and Space Administration, March 1981).

Photo credit: Dennis de Cicco/Sky & Telescope Magazine

In each time zone, the daily rising of the Sun synchronizes internal clocks throughout the ecological community.

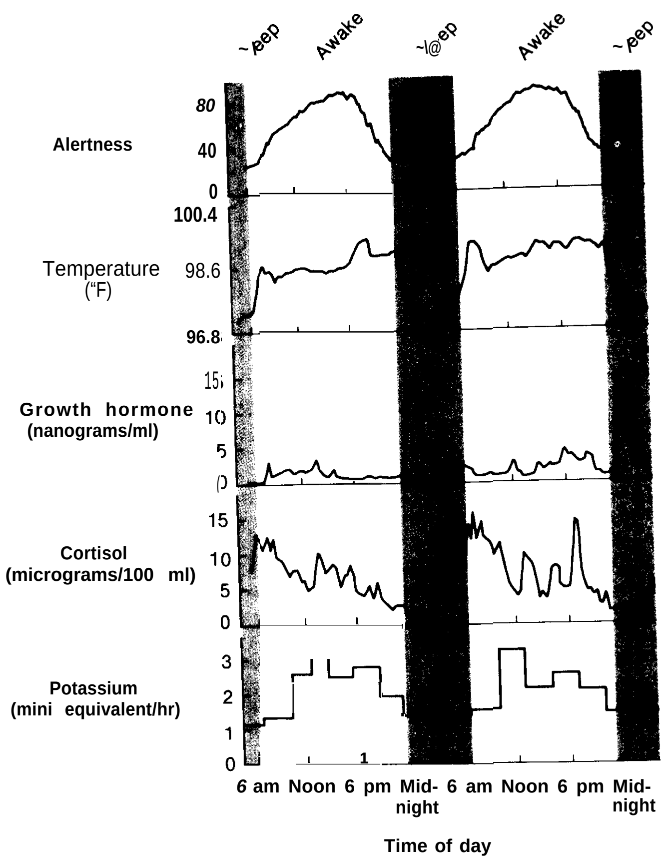
While biological rhythms are driven by an internal clock, external factors usually entrain, or synchronize, those rhythms with the physical environment. The degree to which an internally generated rhythm is affected by environmental factors varies with the species and the function being controlled. The ease with which a function adjusts its rhythm to environmental cues will determine the degree to which the timing of that function can be altered. In humans, this has direct implications for the ability of the body clock to readjust following changes in schedules.

Circadian Rhythms

While biological rhythms have cycles ranging in length from minutes to months, those in synchrony with the 24-hour rotation of the Earth are probably the most extensively studied. These circadian rhythms are usually 20 to 28 hours long, and many physiological and psychological functions follow such a circadian cycle (figure 2-1).

Recognition that the activities of many plants and animals exhibit rhythms which coincide with the 24-hour cycle of day and night probably dates back to humanity earliest contemplation of the temporal order of nature. The realization that these cycles were 1101 solely a consequence of environmental

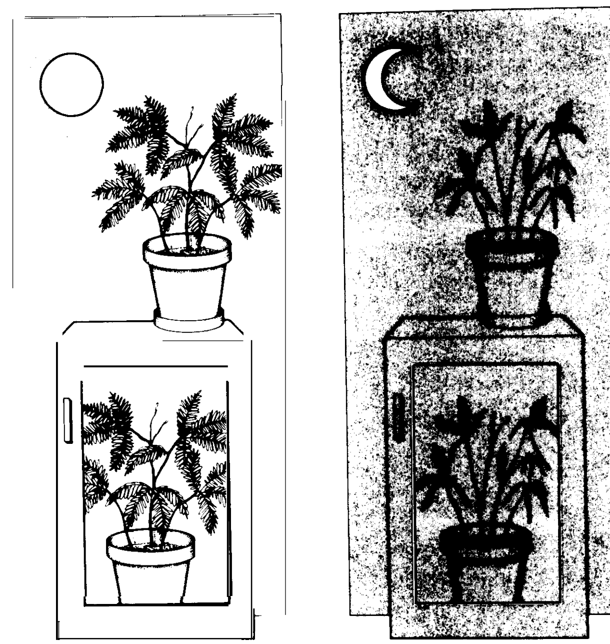
Figure 2-l-Circadian Timing of Various Functions



The timing of some functions that cycle with a circadian rhythm.

SOURCE: Adapted from R.M. Coleman, *Awake at 3:00 a.m. by Choice or by Chance* (New York, NY: W.H. Freeman, 1986).

Figure 2-2—De Mairan's Experiment



De Mairan observed a biological rhythm in plants.

SOURCE: R.M. Coleman, *Awake at 3:00 a.m. by Choice or by Chance* (New York, NY: W.H. Freeman, 1986).

influences did not occur until 1729, when French astronomer Jacques d'Ortous de Mairan studied the actions of a plant that normally opens its leaves during the day and closes them at night (figure 2-2). De Mairan observed that even when kept in the dark, the plant opened and closed its leaves according to the day-night cycle. This indicated that the force driving the plant's rhythms was internally generated (5).

The first observations of circadian rhythms in humans were made in 1866, when William Ogle noted that fluctuations in body temperature varied in synchrony with day and night (5). It was not until more recent times that the endogenous nature of circadian rhythms in humans was characterized (l). To date, research has identified hundreds of biological variables in humans that exhibit a circadian rhythm (5). These functions are both physiological (e.g., body temperature, hormone production, sleep-wake cycles) and psychological (e.g., cognitive performance, memory).

BIOLOGICAL RHYTHMS AND THE WORKPLACE

Humans are diurnal, and for most of history they obeyed the body clock's mandate to be active during the day and sleep at night. However, as civilization evolved, the desire, ability, and need to contravene this pattern of activity grew. The control of fire enabled humans to penetrate the darkness and explore the nighttime world. Since then, technological advances have led the way to societies whose activities extend beyond the daylight hours. This trend was accelerated with the Industrial Revolution and the advent of readily available electric power. In the last few decades, other technological and economic forces, such as the need to operate costly equipment continuously, the requirement of some manufacturing processes for uninterrupted operation, and the increasing demand for 24-hour serv-

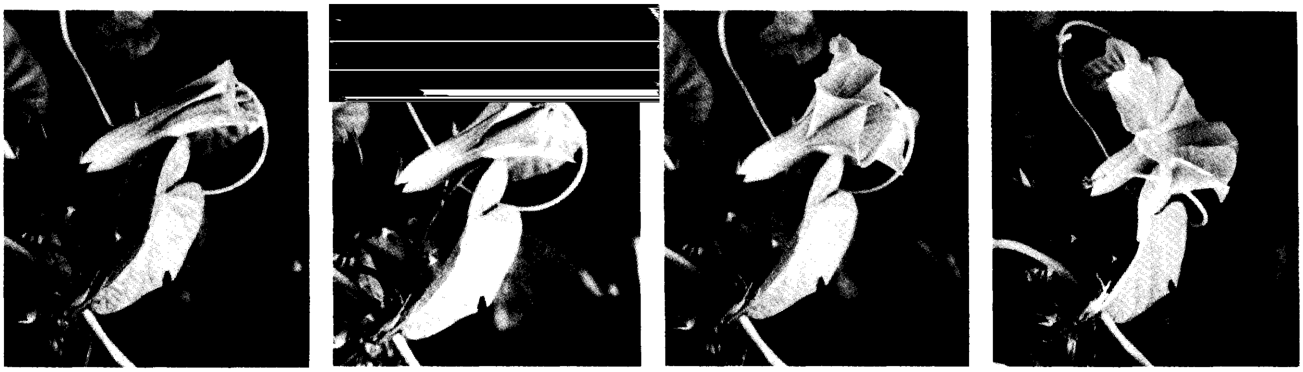


Photo credit: Travis Amos

Flowering in the morning glory, as in many other plants, is timed by a circadian clock.

ices, have contributed to the ever-growing number of occupations that operate around the clock.

As a result, many persons in these occupations work nonstandard schedules that can put them out of synchrony with their body clocks. The term "shift work" is often applied to these schedules, but there is no consistent definition of the term. In this report, it includes evening and night work; split shifts, in which a period of work is followed by a break and then a return to work; rotating shifts, in which the hours change regularly (e.g., from day to evening to night); and extended duty hours, consisting of long work periods (usually over 12 hours).

Many factors shape the experience of individuals working these schedules, and the interactions among them are complex (2-4,8). In addition to disrupting biological rhythms, shift work can cause other physiological factors, such as sleep deprivation and fatigue, to come into play. It can also affect the family and social life of workers, creating a situation in which their schedules do not coincide with those of the people around them. The cumulative effects of these factors can adversely affect the health and performance of workers and can jeopardize their safety and that of the public; however, the degree to which these effects occur, which workers are most susceptible, and the work conditions under which they occur have not been clearly delineated.

Many occupations require 24-hour operations. They include industrial and manufacturing industries (e.g., chemical, steel, paper, powerplants), protective and health services (e.g., police, fire and rescue, hospitals), transportation (e.g., airlines, railroads, trucking, shipping), major construction projects (e.g., dams, tunnels), and, increasingly, services (e.g., retail stores, financial institutions, entertainment and recreation, specialized services such as overnight deliveries). It is estimated that one in five workers in the United States does not regularly work a standard daytime schedule (6). As a result, about 20 million workers are exposed to a wide range of schedules that differ in the duration of the work period, the hour of day, and the stability of the schedule. Each of these schedules has different effects on workers' biological rhythms and related factors as well.

FEDERAL GOVERNMENT OVERSIGHT

In the United States, the laws that govern hours of work consist of the Fair Labor Standards Act, which was enacted in 1938 and established a standard 40-hour workweek, and various hours of service acts, which regulate maximum hours of work for a number of industries, notably transportation. In addition, some States have regulations regarding hours of work.

The Federal Government has broad authority to regulate working conditions that endanger the safety and health of workers through the Occupational Safety and Health Administration (OSHA) of the Department of Labor. In addition, some Federal agencies have the authority to regulate safety and health within their, own jurisdiction. Examples of agencies that have exercised some authority over safety and health issues include the Federal Highway Administration, the Nuclear Regulatory Commission, and the Federal Aviation Administration.

OSHA can address worker safety and health issues by issuing standards that require employers to put in place appropriate protective measures and by inspecting for compliance. Where standards are not available, OSHA can act to increase safety and reduce health risks by enforcing the general duty clause of the Occupational Safety and Health Act. This requires employers in an industry that recognizes the existence of a serious hazard to take feasible steps to reduce the risk of that hazard to workers. OSHA can impose standards and regulations on the workplace when scientifically valid research and empirical data indicate that conditions impose a significant risk of harm to workers.

In the case of biological rhythms and their interaction with work schedules, the collection of data takes a number of forms, including basic scientific information on underlying biological mechanisms; applied research examining the human response in laboratory and field settings; and statistical information on the occurrence of injuries, mishaps, deaths, and health problems in the workplace and the conditions under which they occur, as well as demographic statistics on schedules being worked. The Federal Government's role in the collection of this information cuts across all of these. Federally funded extramural and intramural basic science research programs, through agencies such as the National Institutes of Health and the Air Force Office of Scientific Research, are a means of providing information on basic biological mechanisms. Federal or federally sponsored applied research programs can be conducted under the auspices of agencies such as the Centers for Disease Control (through the National Institute for Occupational Safety and Health) or other agencies, such as the National Aeronautics and Space Administration, the Department of Transportation, the Department of Defense, and the Nuclear Regulatory Commission. Collection of workplace statistics is done by OSHA and the Bureau of Labor Statistics within the Department of Labor.

Concerns about the effects of various work schedules on the health and safety of workers and the impact they could have on the public raise questions about the level of Federal involvement in the regulation of work hours and the types of schedules employed in various occupations. This concern is coupled with questions regarding the extent of knowledge about work schedules and their effects. In 1984, the Subcommittee on Investigation and Oversight of the Committee on Science and Technology of the U.S. House of Representatives held hearings on biological rhythms and shift work scheduling. It is interesting to note that many questions posed at that time still await answers, namely:

- What types of schedules are being worked and by whom?
- What are the precise effects on the health, performance, and general well-being of workers who work nondaytime hours?
- What kinds of effects occur in what kinds of schedules?
- Who are the workers who may be most affected?
- What factors contribute to any effects that are observed and to what degree?
- What are the implications of these effects for worker safety and the safety of the public?
- Most important, is enough known at this time to recommend specific 'guidelines or regulations?

This report discusses the current theories and ideas that pertain to these questions and describes the latest developments in the effort to answer them.

THE OTA REPORT

The primary focus of this report is the human body clock and what occurs when it is disrupted by various types of work schedules. In the seven chapters that follow, the Office of Technology Assessment (OTA) examines possible interactions of work schedules and biological rhythms and their implications for the American worker and the public. In addition, OTA examines the role of Congress and the Federal Government in addressing the public policy issues raised by this topic.

Chapter 3 reviews the most recent developments in understanding the body clock. It presents basic scientific information about biological rhythms, how they are regulated by the body, and how extrinsic factors can affect their functioning. In chapter 4, the forces driving the use of nonstandard work schedules are presented, as is a description of the population of U.S. workers who work them. Chapter 5 examines what can occur when work schedules impinge on the normal activity of the body clock. How disruption of biological rhythms interacts with other factors to affect the health, performance, and well-being of workers is described. The implications of these effects for the public's safety and possible interventions to counteract them are also addressed. Chapter 6 discusses the Federal role in regulating work hours and overseeing worker health and safety. Finally, in order to highlight the variety of settings in which nonstandard work hours can be encountered, OTA has selected three case studies to examine in closer detail. These case studies also represent occupations in which any adverse effects of nonstandard work hours that occur may affect the public welfare:

- nuclear powerplant control room operators (ch. 7),
- registered nurses and resident physicians (ch. 8), and
- the military (ch. 9).

CHAPTER 2 REFERENCES

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