2 SOME APPROACHES AND PITFALLS

THE READINGS:

Accident research is highly heterogeneous in content and emphasis. It ranges from intensive studies of the role of specific variables to broad-scale investigations of accident incidence. There are many types of accidents, and many factors, often interrelated, that may be significant. This complexity is soon apparent to those approaching the subject for the first time, and it remains a source of concern to established investigators. In view of this, it is our purpose in this chapter to introduce some of the general concepts which have proved useful. We shall consider also the use of incidence rates derived from large populations—for example, that of the United States—and note the limited usefulness of such compilations in the determination of causation. Finally, we shall emphasize that, unless he uses appropriate methods and bears in mind the complexity of the field, the research worker is likely to overemphasize the importance of the variables with which he is particularly concerned.

The Need for a Balanced Approach

Despite their frequent biases and lack of specificity, data summarizing the incidence of accidents in large populations can be used profitably, especially in identifying the general types, numbers, and trends of accidents. They are also used to support statements to the effect that accidents constitute a major *practical* problem and that as such they justify the application of those same concepts and methods that have proved fruitful in the understanding and control of related problems.

This emphasis on the practical has proved very useful to those seeking encouragement and support for accident research and control programs; it has, in fact, facilitated many of the investigations cited in this volume. It tends, however, to divert attention from theoretical and interdisciplinary problems not recognized as directly relevant to the solution of specific, practical problems. This emphasis on what is thought to be the obviously practical has been coupled with and has engendered a narrowness of subject matter, concept, and methodology which has unquestionably impeded progress in the field. The literature is largely parochial, fragmented, and divergent, and even where this is not the case it is difficult to find contributions which are constructively synthetic rather than merely eclectic.

These deficiencies are well illustrated by a number of the selections in this volume, even those chosen as the best available examples of their types. With the exception of the paper by Gordon, however, which follows below, and of the many papers that are to various extents in its lineage, there have been few even partially successful attempts to provide conceptual frameworks within which the *entire* subject of accidents, regardless of type, might be approached systematically.

Such an over-all synthesis must provide a framework within which it is possible to consider not only accidents in large populations but also those occurring to individuals. It must be equally adaptable to accidents in which the physical characteristics of the environment are of primary importance and those in which medical, physiological, behavioral, and other more "human" factors are dominant. For example, it must be equally useful in the analysis of accidents as diverse as those involving explosions, falling cornices, and equipment failures, at the one extreme, and those involving ruptured aneurisms and psychological upsets, at the other. It must serve also as a device for the recognition and categorizing of factors and their interactions, to be considered in the systematic analysis of any accident or group of accidents.

Ideally, the approach must be intentionally multifactorial and must avoid *unsupported* presuppositions as to the primary causes either of accidents in general or of those in the specific group under study. Unsupported presuppositions, as we shall note in subsequent chapters, have proved a stumbling block to many who, in discerning the unique contributions of their own disciplines, have attempted to explain essentially all accident phenomena in terms of the concepts and groups of variables with which they are customarily concerned. Nonetheless, it must be recognized that much good work can be, and has been, done with the use of approaches which are not generally satisfactory.

Attempts to explain phenomena in narrow terms are characteristic of the development of a new area of scientific concern. This has been seen repeatedly in medicine and biology, as indicated, for example, by the formerly common phrase "the germ theory of disease." This early phase is followed by a second, in which more sophisticated research is accompanied by increasing emphasis on the apparent complexity of the field and, concomitantly, by despair as to the possibility that a relatively simple, unifying conceptual framework might be developed. Accident research in general has reached this second phase,[1] and we could cite many dogmatic statements that it is impossible for it to progress further. This view, however, is not supported by the evidence and is challenged in the first reading—a discussion of an open-ended but nonetheless structured approach to accident phenomena.

THE EPIDEMIOLOGY OF ACCIDENTS

—*John E. Gordon, M.D.*

According to Westbrook[2] the importance of a scientific paper can be measured in part by the frequency with which it is referred to in others' work. Judged by this criterion, Gordon's work ranks high, since it has been referred to, discussed, and productively applied by many of the authors represented in this volume. This is not to say that the use of its framework poses no problems, a point to be discussed below; but it represents that great rarity in accident literature, a practically useful device for at least approaching the entire field.

Epidemiologic Methods in Accident Research

To understand the importance of Gordon's paper, it is necessary to recall that it was written in 1948. That decade, despite the world conflict which dominated its first half, witnessed dramatic progress in the control of important infectious diseases. The sulfa drugs, the first of the antibiotics, DDT, and greater understanding and use of immunization and related measures had all contributed to sharp declines in the incidence and prevalence of such diseases. As a consequence, those concerned with public health slowly began to realize that the substantial increases in the *relative* importance of accidents could no longer be ignored. This realization is reflected in many of the papers that follow. Many public health workers, however, then, as now, appeared to have had little understanding of or feeling for this area and for its close relationship to the concepts, subject matter, and methods which had classically been the concern of the profession. Gordon's paper contributes toward the resolution of this continuing problem.

In this context, it stands as a carefully organized and well-documented statement of the appropriateness and potential utility of applying to accidents an approach long applied to more traditional problems. Gordon points out that epidemiology has been successfully "extended from its original restriction to the communicable diseases to a broad application to mass disease of man; to cancer, diabetes, congenital anomalies, and many others." He adds, however, "It is not so generally appreciated that injuries, as distinguished from disease, are equally susceptible to this approach, that accidents as a health problem of populations conform to the same biologic laws as do disease processes and regularly evidence comparable behavior." This introduction is strongly supported by a series of examples drawn in parallel from the infectious disease and accident literature.

Gordon makes quite clear that by "the epidemiology of accidents" he means those aspects of human ecology that are especially pertinent to the occurrence of accidents in human populations. Since these unplanned events relate to virtually all of the interminably complex aspects of the human situation, he explicitly extends to this area the conceptual framework found useful in handling the same types of variables in the study of the gross incidence of infectious and noninfectious diseases. Within this framework he demonstrates that it is possible to delineate patterns in the distribution of these otherwise seemingly chance events which may lead (and in many instances have led) to an understanding of their causation and to the possibilities for their control. The approach is used both to describe the frequency and distribution of accidents, especially in large populations, and to organize the search, particularly in more homogeneous groups, for factors etiologically associated with increased incidence, facets of the epidemiologic method which MacMahon *et al.*[3] have defined as "descriptive" and "analytic."

Applied to any medical problem, this approach involves essentially sorting out the mixture of factors associated with increased incidence. It is an ordering process analogous to that used in approaching any other similarly mixed bag of events whether, for example, "fevers" or meteorological phenomena. It is the first step in focusing down from the gross to the specific.

The readings in this chapter, in contrast with those in Chapters 4 through 9, are concerned chiefly with the descriptive epidemiology of accidents as they occur in large, heterogeneous groups. Such patterns are usually so general that their description contributes but little to the understanding of causation in any immediate sense, a fact well understood by many of those working at this level of analysis. Work of this type represents, however, a necessary step without which it is often impossible, in practical situations, to identify the general areas from which an accident problem is originating and to determine their relative importance.

THE CONCEPT OF CAUSE

Although the terms "cause" and "causation" are often used in these descriptive papers, emphasis is placed on the qualitative and quantitative definition in statistical terms of the parameters, and their relationships, associated with high rates of occurrence. This level of analysis is often far removed from those which emphasize the identification of specific "causes." Half a century ago Bertrand Russell pointed out that the "notion of cause" is foreign to what he referred to as the more established sciences, and that their concern, rather, is with the delineation in mathematical terms of the interrelationships of the variables with which they deal.[4] Without taking sides in the attack on determinism launched by Russell and others, one may note that this emphasis is becoming increasingly widespread in accident research. A paper by Shaw and Sichel, for example, claims the successful *identification*, for uniform exposure, of *individual* accident rate patterns, derived without substantial attention to the activity of specific "causes."[5] Other examples, easily identified by their complete or substantial avoidance of the terms "cause" and "causation," are to be found in the chapters that follow. Other authors use the term "cause" chiefly as a synonym for mechanisms of injury (*e.g.*, "piercing instruments") without indicating or recognizing that this often contributes little to the understanding of the factors that led up to the accident.

Gordon's approach represents an intermediate position well illustrated by his subtitles. Progressing from a discussion of "Movements of Disease and Injury According to Time," he considers "Accidents as an Ecologic Problem" and points out the usefulness in given situations of considering "causation . . . as something more than [a function of] the agent directly involved. . . . Rather it is a combination of forces from at least three sources . . . the host, . . . the agent, . . . and the environment in which host and agent find themselves." This stress on the interaction of multiple causes is further developed by consideration of categories of characteristics of host, agent (see below), and environment which, though always somewhat important, may be especially so in specific instances. Although characteristics of many types are considered, of particular interest in connection with Chapter 8 is his statement, "Whatever the kind or nature of mass disease or injury, the part exerted by the socioeconomic environment is probably the most neglected of any epidemiologic influence. . . ."

Unfortunately, in the accident literature and elsewhere, the term "epidemiology" is given a wide and confusing variety of meanings, and Gordon's usage differs from that represented in subsequent selections.* Moreover, members of collateral disciplines have tended to regard epidemiology as primarily an extension of the concerns and methods of their particular fields. This has been especially true of workers close to the classical subject matter of public health, and the increasing representation of additional disciplines in public health research has served to confuse the matter even further.

Such views overlook the fact that, although the variables and substance with which such disciplines commonly deal are relevant to epidemiology, they do not contribute the bulk of the subject matter with which it has been and is now concerned,

* Gordon has defined epidemiology as the study of medical ecology in all of its ramifications. *This definition is preferred by the present authors.*

including as it does matters as diverse as incubation periods, the ecology of nonhuman vectors, the effects of ionizing radiation and air pollutants on populations, secular variations in disease incidence and prevalence, and various medical correlates of socioeconomic indices. Since the wellsprings of accidents are similarly diverse and involve many of the same human and environmental variables, we have not in this volume approached accident research from only one disciplinary viewpoint but rather we have, in the manner of the epidemiologist, attempted to emphasize the manifold ways in which the particular concerns, viewpoints, and tools of various disciplines may be brought productively to bear on the subject. For this reason, Gordon's paper, with its emphasis on multiple causation, ecologically considered, is an appropriate introduction to this broad sampling of accident research.

EXISTING RATES for deaths from accidents and violence remain numerically at almost the identical level of 1900, 88 per 100,000 population in 1900 and 88 in 1946. The relative position among public health problems is at a higher level, since these conditions have advanced as a cause of death in the United States from sixth place in 1900 to third in 1946.

Industry and various governmental agencies have given much attention to the accidents that occur in the places where men work, in public areas, and in relation to motor cars. Accidents in homes outdistance any other class in the losses they cause, whether judged by deaths, by the permanent defects that follow, or by temporary disability. Like all programs for the prevention of mass disease and injury, that directed toward accidents is necessarily a team effort involving a number of agencies and a variety of disciplines. Although health departments have an obligation in all accident prevention, a better record for home accidents is believed to depend largely upon what health departments do in that field. If home accidents are primarily a public health problem, then that problem is reasonably to be approached in the manner and through the technics that have proved useful for other mass disease problems. This includes first an epidemiologic analysis of the particular situation, an establishment of causes, the development of specific preventive measures directed toward those causes, and finally a periodic evaluation of accomplishment from the program instituted.

No need exists in these days to trace the way in which the epidemiologic method has extended from its original restriction to the communicable diseases, to a broad application to mass disease of man; to cancer, diabetes, congenital anomalies, and many others. It is not so generally appreciated that injuries, as distinguished from disease, are equally susceptible to this approach, that accidents as a health problem of populations conform to the same biologic laws as do disease processes and regularly evidence a comparable behavior. This is readily indicated by an initial comparison of representative diseases and injuries according to frequency distributions in time, an epidemiologic characteristic of established value in separating one mass disease from another, and in distinguishing kinds of behavior.

MOVEMENTS OF DISEASE AND INJURY ACCORDING TO TIME

The point epidemic is perhaps the most arresting of all distributions in time, that circumstance where a sharp aggregation of cases occurs within a brief interval as the result of a single agent acting during a prescribed and limited time (Figure 1). A circus train backed up to a standpipe in the

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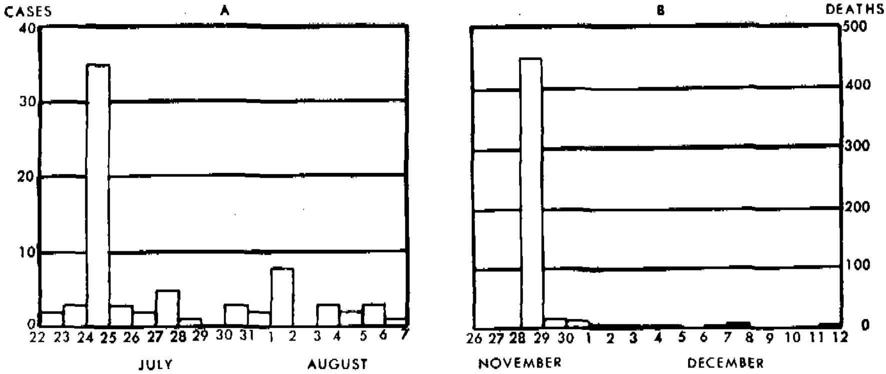

FIG. 1. Point epidemic: (*A*) Typhoid fever in a circus, July 22 to August 6, 1934; (*B*) Cocoanut Grove nightclub fire, Boston, November 28, 1942.

Pittsburg railroad yards, filled its tanks with untreated river water, and some two weeks later typhoid fever exploded sharply as the troupe played Dayton, Ohio. The deaths from accidents which occurred in the 1942 Cocoanut Grove night club fire in Boston were of the same order, the result of a single causative agent striking once and leading to an explosive outbreak with subsequent scattered deaths due to a more resistant host or a lesser activity of the agent. The result of a Florida hurricane would serve equally well in illustration.

The classical outbreak of amebic dysentery in 1933 in a Chicago hotel was characterized by three successive peaks in incidence, a cyclic distribution caused by periodic contamination of the water supply. A similar cyclic distribution of injuries occurred among soldiers of an infantry division in France in 1944, when three successive and distinctive outbreaks of cold injury and trench foot followed major military activities and increased exposure to cold, with the central and major event readily identified as a consequence of the Battle of the Bulge.

Other diseases are characterized by a non-fluctuating endemic prevalence of which tuberculosis furnishes a good example, case rates for the United States during the years 1943-1947 adhering closely to a level of about 90 per 100,000 population. Certain classes of accidents conform to the same pattern, notably home accidents, where year after year the death rates show little variation, sometimes a few more than 25 per 100,000 persons, and uncommonly a few less.

A well defined annual seasonal variation in frequency distribution is also a common characteristic of many communicable diseases. Scarlet fever in Massachusetts regularly attains a maximum frequency in the winter months of January and February (Figure 2). An equally regular annual periodicity is shown by motor vehicle accidents for the same state and for the same years illustrated, again a winter prevalence except that the peak develops somewhat earlier, in November and December.

The long-term trend in frequency distributions by time is another common method of evaluating the movements of disease, and a method that often serves importantly in determining the effectiveness of preventive measures that have been introduced. Injuries show typical trends (Figure 3), as definite as those of diseases, sometimes with frequency distributions maintained at a more or less fixed level, sometimes with a well defined tendency to move upward or downward. The downward trend in deaths from tuberculosis in the United States during the present century is universally known, from close to 200

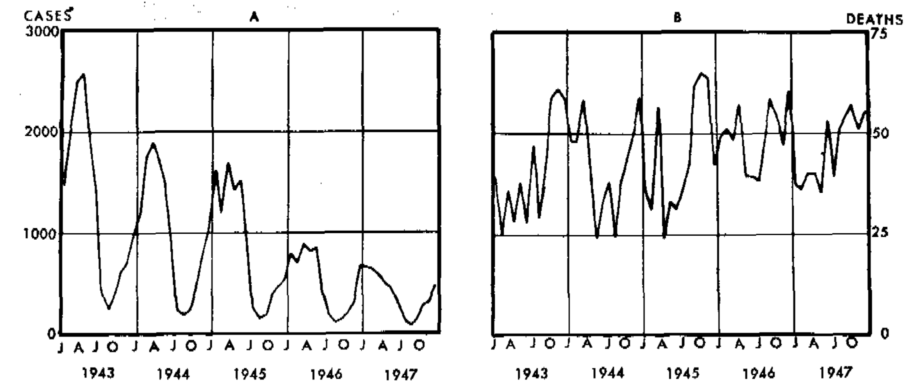

Fig. 2. Annual seasonal incidence: (*A*) Scarlet fever, Massachusetts, by months, 1943-1947; (*B*) Motor vehicle accidents, Massachusetts, by months, 1943-1947.

deaths per 100,000 population for the registration area of 1900 to a level consistently below 50 for the same region in the years since 1937. The frequency curve for deaths from accidents other than motor vehicle accidents during the same period and for the same area was at a more or less constant level of about 85 per 100,000 during the first 10 years of the century; thereafter with a significant downward movement, with the past 15 years showing little variation although the level is now at about 50. Accidents as representative of the class of injuries evidently follow as distinctive movements in time as do diseases. It remains to determine whether the same biologic laws that govern occurrence and causation also act in respect to injuries.

Accidents as an Ecologic Problem

Irrespective of whether disease and injury be looked upon as affecting the individual, or as the mass effect exerted upon a community, causation is to be interpreted as something more than the agent directly involved, a germ in infectious disease or the loose board in a home accident. Rather it is a combination of forces from at least three sources, which are the host—and man is the host of principal interest—the agent itself, and the environment in which host and agent find themselves. Neither one nor the other invariably exerts the principal effect, which provides the assumption that similar disease phenomena can arise from dissimilar causes.

An established and satisfactory equilibrium or adjustment between man and his environment leads to the situation called health. A significant disturbance of that equilibrium is the basis for disease or injury. The disturbance may occur either through principal action of the agent, because of a characteristic of the host, or as a function of environment, but most often through some combination of the three. These are the fundamental factors in causation. The mechanisms involved—how they interact to the eventual production of a pathologic condition, in pathogenesis of individual disease, or in the genesis of epidemics—is also a practical consideration, but the essential question is what are the basic causes of the disease or injury. This is true because remedy must be suited to the whole of cause, as it lies in host, agent, and environment. Can these broad biologic principles be fitted to an interpretation of injuries, as they have been to disease, whether communicable or non-communicable?

Host Factors in Accidents

Because the object or agent which directly gives rise to an accident is so evident—the faulty pavement, the scalding water, the unguarded poison—the common tendency to consider only that factor in a causative relation is readily understandable. An enveloping darkness, or rainy weather, or a crowded tortuous thoroughfare are also not so difficult to interpret as contributing to accidents. But the people who get hurt, they are only the poor victims; and yet when the question is examined, probably more causes of accidents lie within what we choose to call host factors, within people themselves, than in any other of the three parts of the triad which explain disease and injury. The host patterns of persons who suffer from accidents are of the same general order as those long recognized in many disease processes.

Age—Deaths from home accidents in the United States in 1945 were most frequent among the very old, past 65 years, and among the very young, aged 0 to 5 years, with the loss of life far less during the active periods of life, 5 to 65 years, when conceivably the opportunity for accidents is greater and the risk much enhanced. The distribution of deaths by age is so like that for deaths from pneumonia and influenza of the same region and for the same year, in the United States in 1945, that the two are almost interchangeable. However, the whole significance of age as a host factor is not revealed by the absolute weight of accidents at various ages, for the situation is altered when the interpretation is in terms of relative importance. While the death rates for accidents are greatest at the extremes of life, the problem centers among children and young adults when considered according to rank among causes of death (Figure 4).

Sex—Difference in attack rate by sex is another characteristic useful in distinguishing community diseases, from the outstanding predominance of males over females provided by tularemia and undulant fever, where other features than sex evidently enter, to the regular although less marked excess of males that characterizes mumps and other diseases of childhood. The spread between death rates for males and females for accidents of all forms is noteworthy, and particularly so when selected types of accidents are compared. Fatal accidental injury through falls is more than twofold greater for females than males at age 65 years or more, a reversal of the experience during childhood and for young adults.

* * *

Agent

The agents concerned with injuries and with accidents, like those of disease, are variously of physical, chemical, and biologic nature. The importance of the several classes is greater in some types of accident than in others and the kind of agent within a class is potentially great. Information about the agents concerned in accidents is none too

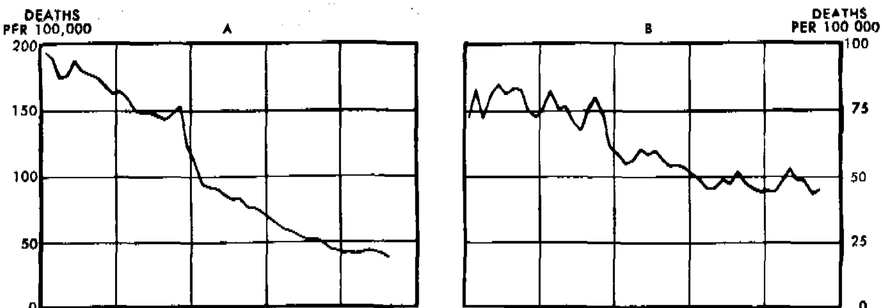

FIG. 3. Long-term trend: (*A*) Deaths from tuberculosis, U.S. Registration Area of 1900, 1900-1946; (*B*) Deaths from accidents, excluding motor vehicle, U.S. Registration Area of 1900, 1900-1947.

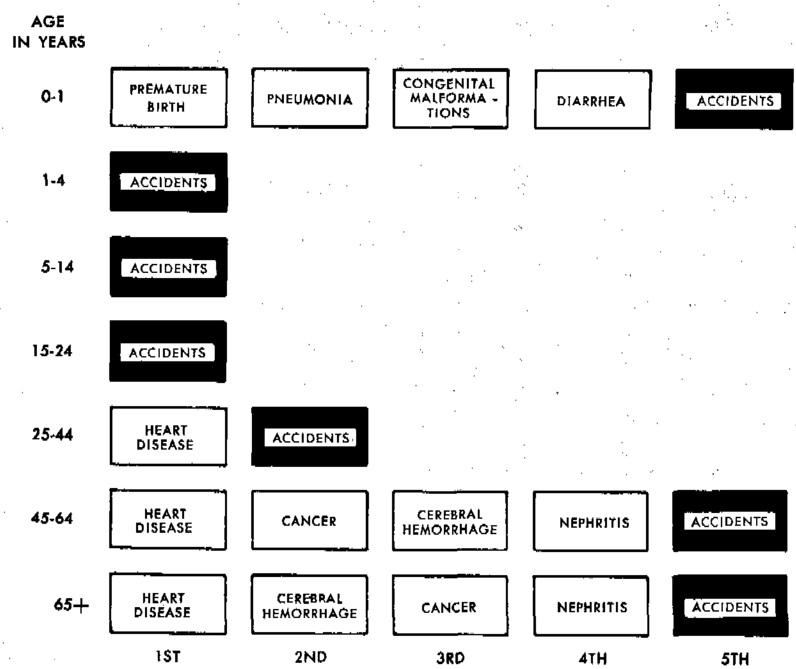

FIG. 4. Principal causes of death, by age, United States, 1945.

satisfying because of the common failure to distinguish mechanism from actual agent.

The causative factors in accidents have been seen to reside in agent, in the host, and in the environment, The mechanism of accident production is the process by which the three components interact to produce a result, the accident; it is not the cause of the accident. Kinds of mechanism serve to advantage in classifying accidents by type, with a particular event ascribed to cutting or piercing, to collision, or to crushing, and yet the agent in all three instances is a glass panelled door. Conversely, a fall may be related to such dissimilar agents as a faulty ladder, a playful pup, or a misplaced handbag.

The significance of agents in the problems of causation becomes more apparent when the kind and concentration are related to the same fundamental features of time-place-person relationship that is the basis of the epidemiologic method. This may be illustrated (Figure 6) by the geographical distribution of cases of typhoid fever and of deaths from lightning, with the dominant "reservoirs of infection" and factor of community dosage as evident for the one condition as for the other.

ENVIRONMENT

The limited perspective with which environment is commonly viewed is open to improvement by considering it as composed of three major elements, the physical, the biologic and the socioeconomic, a concept elsewhere discussed in detail. The physical environment has to do with matters of climate and weather, of season and topographical affairs, with soil and terrain, and the other physical features of the world where man lives. The biologic component of the environment can be taken to include the universe of living things that surrounds man, all else than man himself; while the socio-economic part of environment is that which comes into play through association of man with his fellow man. Environment so considered exerts an influence on disease sometimes through direct action on host or

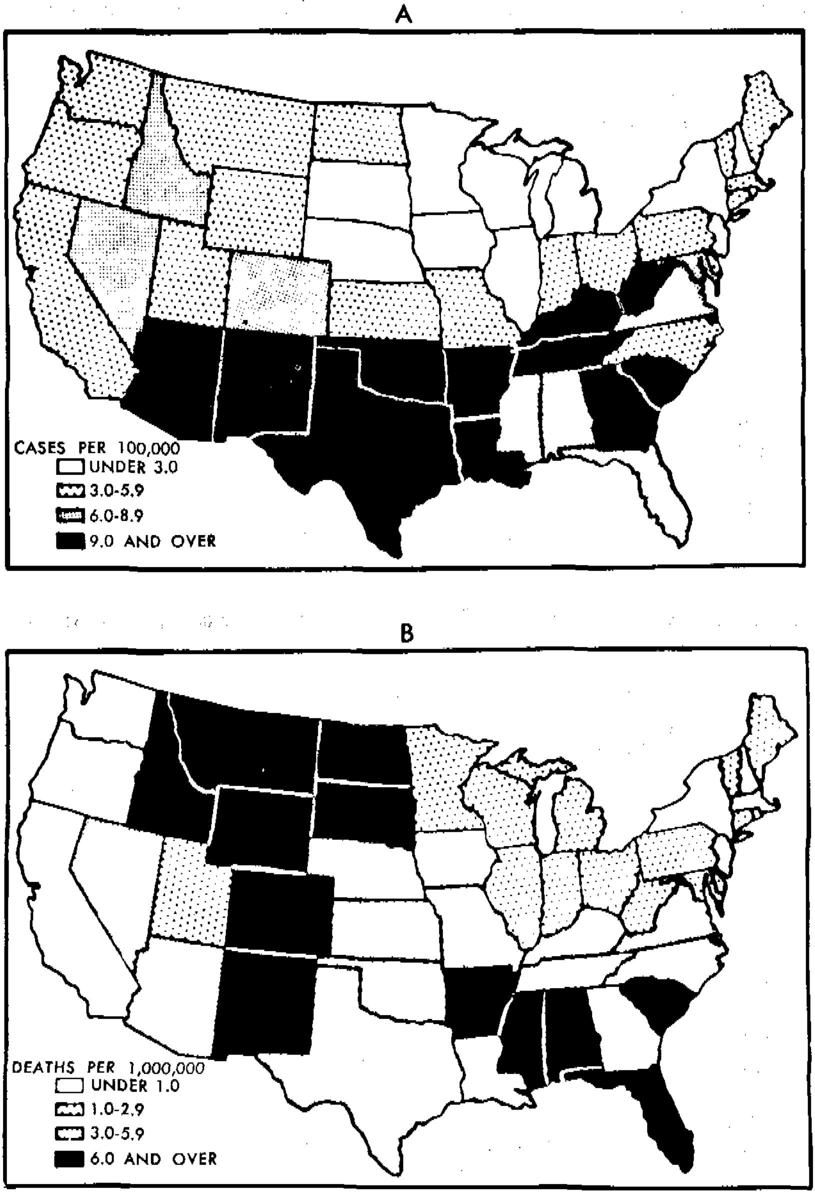

FIG. 6. Geographical distribution: (*A*) Cases of typhoid and paratyphoid fever, United States, 1940-1944; (*B*) Deaths from lightning, United States, 1940-1944.

on agent, and sometimes on the mechanisms which bring host and agent together or determine their interaction. The results of environmental influences are to be measured by the character of the disease process that results, by the extent and nature of the frequency distributions that follow, and often by both. The three factors of environment are now considered as they act in determining distributions of accidents.

Physical Environment

The geographic differences in frequency of deaths from accidents of all forms are well recorded in the United States over many years; the highest rates are in the far West and in Florida, the lowest in the Middle Atlantic and New England areas. The general pattern by no means holds for the various classes of accidents, notably home accidents, nor does the gross differentiation by states permit the individual community to judge its particular problem logically. This has been recognized to the extent that some cities determine the frequency of accidents by political subdivisions such as wards or census tracts, and states like Tennessee and Kansas have effected divisions by counties. Further division can be made according to classes of accidents, for example, those that occur in the home or in association with motor vehicles.

The contrasting frequency of diphtheria and scarlet fever in the cities of Sao Paulo and Santos in Brazil is a striking example of the effect of climate on disease. The average annual mortality rates per 100,000 in Sao Paulo were for diphtheria 10.8, for scarlet fever 7.6; in Santos, diphtheria 3.1 and scarlet fever 0.3. The two cities only 49 miles apart are climatically wholly distinct since Sao Paulo high in the mountains has a temperate climate, while Santos is on the tropical sea coast. An equally striking effect of temperature is seen in the frequency of cold injury among American troops in France in World War II. As temperatures dropped from November through January, the number of soldiers developing trench foot progressively increased.

A seasonal effect on injury and accident as striking as any that characterizes a communicable disease can be had by comparison of the distribution curves for cases of poliomyelitis and accidental deaths from drowning in the United States in 1945, the two curves being almost identical. This random choice illustrating a summer prevalence is easily duplicated, for instance by deaths associated with falls at all ages and suffocation of infants aged less than one year, which are typically winter diseases. The examples are sufficient to establish the principle that types of accidents have seasonal variations which can be as regularly recurring and as well marked as those for infectious or other disease processes.

The frequency of ascariasis in a rural area of West Virginia and in rural China is presented as an influence of soil and terrain on the frequency of infestation with an intestinal parasite. The rates for children under 10 years were respectively 58 per cent and 82 per cent. The introduction in West Virginia of the socio-economic factor of shoes being worn as age advances leads to comparative rates of 20 per cent and 63 per cent for those aged 40 years or more. Terrain can likewise act on motor accidents, as seen in a comparison of death rates in Rhode Island and in Arizona, where the regularly maintained ratio is 1 : 4 although assuredly analysis would show strong effects for socio-economic environment and from host factors, in addition to the character of the countryside.

Biologic Environment

The biologic factor of environment has a lesser significance in the causation of accidents, compared with the outstanding part it plays in such mass diseases as malaria and rabies. That the principle holds, that environment in relation to accidents is also to be interpreted in terms of the three components already differentiated, is substantiated by a consideration of such events as the home accidents associated with pets, with poisoning through action of snakes and arthropods, and similar incidents related to the animate things that live with man.

Socio-economic Environment

Whatever the kind or nature of mass disease or injury, the part exerted by the

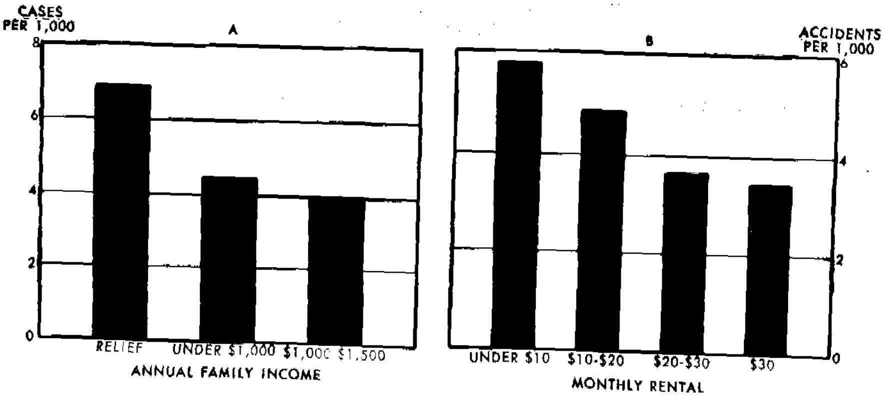

FIG. 7. Influence of socioeconomic environment: (*A*) Pneumonia, cases per 100,000, by annual family income, National Health Survey, 1935-1936; (*B*) Home accidents, cases per 100,000, by monthly rental, National Health Survey, 1935-1936.

socio-economic environment is probably the most neglected of any epidemiologic influence, and accidents are not different in this respect from any other causes of damage. Only scattered information can be put together, that arising from the National Health Survey of 1935 being most instructive. The quality of housing (Figure 7) as judged by the amount of income or rental paid has been repeatedly demonstrated as an influence on the frequency of both communicable and non-communicable disease. It is not surprising that the same causative factors which act so strongly on the frequency distributions of pneumonia are also a determining influence with accidents.

The demonstrated correlation between disease and occupation, as in tularemia where hunters and housewives are the groups most affected, is in complete agreement with the differences noted for accident rates according to occupation. Deaths per 100,000 for persons engaged in mining, quarrying, oil and gas wells were in 1947 about 170; for construction work and those in agriculture about 50.

The changing frequency in the incidence of the common communicable diseases among rural and urban populations is commonly advanced as a feature of modern disease behavior related to social and economic conditions. It is no more definite than the transition noted for motor accidents. Deaths from this cause were dominantly a feature of urban populations 25 years ago, but the recent shift is of such extent that rural death rates now exceed those of urban areas.

THE EPIDEMIOLOGIC APPROACH TO ACCIDENTS

The idea that injuries as they affect groups of people could be profitably approached through epidemiologic methods grew out of a real and pressing experience in World War II. A type of cold injury, trench foot, involved thousands of men, and was a major cause of disability and lost man power. The initial inclination was to look upon the cause as cold, which could neither be eliminated nor adequately controlled in an army operating under field conditions. If not cold, then the cause was deficiencies in clothing and equipment. It soon became apparent that other factors were of greater relative moment, the kind of military operations, the terrain through which troops operated, the management of troops, and an intangible host factor called foot discipline. Occupational components of a division were not uniformly affected, for commonly some 94 per cent of cases were among the 27 per cent of riflemen.

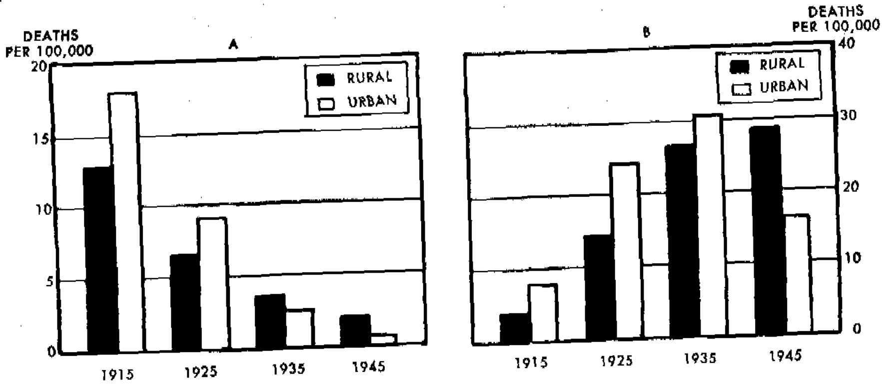

FIG. 8. Urban and rural distributions: (*A*) Deaths from diphtheria, per 100,000 population; (*B*) Deaths from motor vehicle accidents, per 100,000 population; United States, 1915-1945.

Two units operating under similar conditions were disproportionately affected, and the explanation was sometimes related to host, sometimes to the agent, and sometimes was found within the environment. The problem of prevention resolved into a determination of the specific factors contributing to cold injury of a particular unit. From knowledge of those factors a specifically directed program of correction was evolved.

With a return to civilian interests, it seemed reasonable to suppose that accidents as a type of civilian injury could be approached in similar fashion and a study was made of home accidents. The broader presentation given here is advanced in the belief that the method is usefully applicable to accidents generally.

That accidents and disease, as they affect groups of people, so frequently show similar distributions is no reason to assume identical causes; indeed, the expectation is that they are different. The illustrations presented here were purposely drawn from a wide variety of accidents and diseases, to the end of demonstrating that both great classes of morbid conditions of man are governed by broad biologic laws; that in their action on groups of people they are the resultant of the total forces within a universe, of an ecologic entity. An observed behavior is no more a function of all kinds of accident than of all diseases, and conversely a single type of accident, like an individual disease, rarely manifests all the kinds of possible distributions.

Each of the three broad factors in causation has been considered individually to the end of demonstrating principle, but the illustrations themselves, and more particularly the concept of epidemiology as medical ecology, show this to be an over-simplification. All factors are intimately interwoven, each influenced by the other. For a given kind of accident the values are determined by subjecting adequate quantitative data to partial and multiple correlations in search for those conditions of actual importance in the particular situation. Too often the emphasis is on amassing facts with a failure to muster the power that lies in generalization, to develop information from principle or to collect data for a specific purpose and to meet a demonstrated need. A wide range of conditions commonly contributes to the prevalence of an injury. The success of a control program depends on sorting out from the larger volume those that are critically essential. These considerations make epidemiologic analysis a practical approach to an improved understanding of accidents and to a better prevention.

The start is through field investigation, individual case study of the patient, the family group, and the immediate surroundings in which they live. Neither disease nor injury in a community can be effectively prevented or controlled without knowledge of when and under what conditions cases are occurring. The method is fundamentally that so well developed for communicable and other diseases. The nature of the accident is determined, the result evaluated in terms of death or recovery, of temporary disability or permanent defect. The causes are sought through direct investigation of the site of the accident, of the associated circumstances, and of the person who was injured. A principal difficulty is in unearthing the index case, in case finding, for the system of reporting so useful in the study of communicable disease and some few other conditions, is not available for accidents. Deaths from accidents are reported, but what is needed is something more than a knowledge of fatal accidents.

Death is far from being the sole health cost of accidents, or for that matter of any mass health problem. Estimates suggest that for every death from a home accident, some 150 disabling accidents occur, a ratio that is greater than for any other of the accepted classes of traumatic injury. Patients admitted to hospitals serve as a lead to the group likely to suffer permanent defect from accidental injury, for presumably they are the more seriously injured. The kind of information basically essential to a comprehensive preventive program is that which relates to the bulk of lesser events, the accidents that result in temporary and often minor disability. This is to be obtained most surely through organized survey and special studies in selected areas. Much can be accomplished by incorporating the investigation of accidents into the ordinary activities of health departments where public health nurses and others include a consideration of accidents along with other activities which take them to the homes of people.

An analysis of collected data according to the pattern described is believed helpful in understanding the origin of accidents, since it provides a framework into which endless scattered observations can be fitted. It involves first a recognition of the agent involved, second a determination of the mechanism by which that agent comes into play, and thirdly a definition of cause in terms of combined effect originating from host, agent, and environment.

This is not a complicated but a rational and practical approach to the study of accidents. It is a scheme followed by several health authorities. The National Safety Council has made an analysis of home accidents according to this pattern. The investigation form used by the Kansas State Health Department provides a simple means for acquiring and recording necessary data. The method needs wider application if the problem in the individual community is to be adequately met, for it provides the intelligent and specific information upon which to build a program of prevention.

Conclusions

Specifically directed prevention based on an understanding of cause has long guided the attack on communicable and other diseases. The technical method is that of focal attack, a concentrated effort on recognized centers of infection and the causes that brought them into being.

The biologic principles that govern disease as a community problem are interpreted as holding equally well for injuries. A pattern for epidemiologic analysis is presented as a means for a better understanding of accidents, and thereby through improved measures of prevention, a lesser cost in death, defect, and disability.

Gordon's analysis, although it is a landmark in the shift of medical attention to accidents, fails to identify the "agents" required by the host-agent-environment model. Implicit in this model, as applied to the results of infections and other more classical insults to the body, is the concept that each such result is produced by a specific agent acting upon the body and that that pathology can be produced in *no* other way. Thus, such agents as the bacteria that produce tuberculosis and diphtheria are said to be *specific* and *necessary*, since in their absence the injuries they produce cannot occur. Unfortunately, Gordon's analysis fails to identify any such specific agents of accidents and substitutes under this term "agent" portions of the environment (such as "a glass panelled door") which can hardly be of general relevance to accident causation or specific in their results or necessary for those results to occur. For example, lacerations can be produced by many means other than collisions with glass-panelled doors.

This failure adequately to identify agents of accidents has led to much confusion, especially among those not familiar with the more classical uses of its model. More important, it raises the question of whether there are indeed such specific agents of accidents, since if these do exist it should prove possible, as Gordon attempts, to draw useful parallels between accidents and the older concerns of the medical and related professions.

This question is most easily resolved by reference to the use of the term "accident." With rare exception, an accident is defined, explicitly or implicitly, by the unexpected occurrence of physical or chemical damage to an animate or inanimate structure. It is important to note that the term covers only damage of certain types. Thus, if a person is injured by inadvertently ingesting poison, an accident is said to have taken place; but if that same individual is injured by inadvertently ingesting polio virus, the result is but rarely considered accidental. This illustrates a curious inconsistency in the approach to accidents as opposed to other sources of morbidity, one which continues to delay progress in the field. In addition, although accidents are defined by the unexpected occurrence of damage, it is the unexpectedness rather than the production and prevention of that damage per se that has been emphasized by much of accident research. This approach is not justified by present knowledge and is in sharp contrast to the approach to the causation and prevention of other forms of damage, such as those produced by infectious organisms, where little if any attention is paid to the unexpectedness of the insults involved, and only their physical and biological nature is emphasized—with notable success.

In view of these considerations, it is appropriate to ask again whether there are common factors without which accidents—*i.e.*, unexpected injuries to structures—cannot occur, and which would correspond to the specific and necessary causes of the infections. When this question is considered, it becomes apparent that all such types of damage to living and inanimate structures fall causally into a very small number of groups. These groups are defined either by the types of abnormal energy exchanges which produce the injuries or by the specific types of damage produced. Each such type of damage is the specific result of a specific type of energy exchange and it can usually be produced in no other way. For example, the crushing, tearing, and breaking of structure, whether of a fender or of a leg, can be produced only by the transfer to that structure of a sufficient quantity of mechanical energy. The several forms of energy—for example, thermal, electrical, mechanical, and ionizing—thus meet all of the criteria of agents in the host-agent-environment model, and the fundamental problem in accident prevention is seen to be the prevention or mitigation of these abnormal exchanges.†

The recognition that there are necessary and specific causes of injuries and other forms of damage in no way invalidates the concept of "multiple causation." It does, however, invalidate on logical grounds the assumption that because "multiple factors may be of relevance in the *initiation* [italics ours] of accidents . . . therefore there cannot be common factors without which such accidents cannot occur, and which might be susceptible to manipulation."[1]

The increasing recognition of these specific agents of the types of injuries and other damage which define accidents has greatly shifted the emphasis of accident research during the past two decades. The former and almost exclusive concern with the chance aspects of accidents and with the social and other factors leading up to their initiation is now being increasingly balanced by attention to the understanding and prevention of specific types of structural insults. In this light the bulk of the accident research literature has been concerned not with the causation of accidents per se—*i.e.*, with unexpected injuries—but, rather, with the counting of their numbers and with the manifold factors that lead up to their initiation. Because of the bulk of this older literature, however, we have devoted only Chapter 9 to research on the causation of accidents themselves, although these disparate aspects of accident research are represented much more equitably in the work currently being published.

There are two theoretically and practically important results of this recognition of the essential role of abnormal energy exchanges in accident causation. First, it makes clear the nature of the basic events that motivate and define the field and that must be understood and prevented. Secondly, it demonstrates the close parallelism between this area and others long profitably approached at a similarly sophisticated level. Specifically, it leads to an understanding of the fact that many of the same cultural, social, behavioral, environmental, and biological factors that are related to the initiation of infectious and other insults to the body, which have long been the concern of preventive medicine, are also related to the initiation of accidents. It is because these factors can be usefully categorized within the host-agent-environment framework that we have introduced our catalogue of accident research with Gordon's work.

Another problem in the use of the host-agent-environment and related models stems from vagueness. The various pertinent characteristics of host and environment are not so easily defined as the agent, either in terms of their relative importance at the moment of the accident or in terms of their relationships in the events which led to its initiation. For this reason such terms as "secondary," "contributing," and "predisposing" "factors" are used by some investigators. This, however, is not completely satisfactory, since frequently the designation and ranking of such factors are not readily subject to objective analysis and quantification, a difficulty

† See Chap. 9 and references 1 and 6 for elaboration of these points, particularly with respect to: (1) the importance of injury thresholds in determining accident distributions, and (2) the classification of such agents as carbon monoxide, hydrogen cyanide, and others which produce their damage through interference with normal energy exchange.

also encountered when this particular epidemiological model is used in the search for the causes of nonaccidental afflictions of man.‡

The Need for "Controls"

Common sense, a treacherous handmaiden in the interpretation of accident phenomena, suggests that virtually any antecedent event may have contributed in some degree to a given accident and that the closer that event in time and sequence, the greater the magnitude of that contribution. However, it becomes extremely difficult in a given situation, *if attention is paid only to the accidents and to those involved in them*, to rank confidently and reliably the many factors that may have contributed to some extent to their initiation. This has been well illustrated both by the substantial lack of concordance between the lists of contributory factors drawn up by investigators of different orientations in describing the causation of the same accidents* and by the many errors that have resulted from the use of this approach with other subject matter. For these reasons it is usually essential that the frequency distributions of the characteristics investigated be determined and specified both for the accidents and those involved in them and for the conditions and populations from which they are derived. Unless this is done, it is usually impossible to know the extent to which those characteristics are differentially, and hence possibly causally, associated with the occurrence of the accidents in question. When this is done, the non-accident-involved comparison group or groups are referred to as "controls," and the investigation is said to be "controlled," terms used widely in the accident and related literature and frequently in the remainder of this volume.

ACCIDENTS IN THE UNITED STATES

The next selection exemplifies both the use of broadly derived data to indicate the general nature of the accident problem of a large population and the difficulty of interpreting uncontrolled observations. Although it is not a report of research conducted by its authors, it represents a common type—a paper which presents and discusses general descriptive data gleaned from other sources. This example illustrates both the values and the shortcomings of this type of work. In reviewing it, the reader should consider carefully its statements and implications, since several of them, as will be noted below, are not supported either by the data cited or by references. This is a common deficiency of papers of this type, many of which, while presenting some soundly based information, perpetuate a body of folklore supported largely by its frequent citation in other such secondary sources.

‡ An excellent introduction to the problems encountered in reaching conclusions with respect to causation is given by Lilienfeld.[7]

* For an example of this, see the work summarized in reference 8.

LAST YEAR 95,000 Americans died prematurely because of injuries sustained in accidents. The annual number of accidental deaths averaged about 75,000 early in this century, but just before 1930 the yearly average rose to about 100,000 and has remained at that level.

The stability of the over-all accident death toll masks a considerable improvement in many aspects of the accident problem. Death rates per 100,000 population have declined by over 40 per cent, from 99.5, the peak in 1906, to 56.5 in 1956 (see Chart I). For all accidents except motor-vehicle, the decline has been even sharper—more than two-thirds of the peak figure. The 1956 rate was 30.8 per 100,000.*

In recent years accidents have consistently ranked fourth among the leading causes of death. They have been outranked only by such major illnesses as heart disease, cancer, and cerebro-vascular lesions (mainly cerebral hemorrhage). The rise of accidents among the leading causes of death in this century has resulted from the declines in mortality from the major communicable diseases—not from any increase in accident mortality itself.

In 1956 accidents caused 6 per cent of all deaths in the United States, and at ages 1 to 36 they were the leading cause of death. Rates were highest at the upper ages, but accidents were heavily outranked as a cause of death at these ages by heart and other diseases associated with aging. Accidental death rates were nearly 2½ times higher among males than females, and higher among nonwhites than whites.

The costs of accidents are not felt merely in the loss of human lives. In 1956, according to the National Safety Council, accidental injuries numbered over 9½ million, including 350,000 resulting in some degree of per-

* Rates compared over time are adjusted for comparability to a 1940 standard, and thus may not agree with the actual mortality rates in 1956.

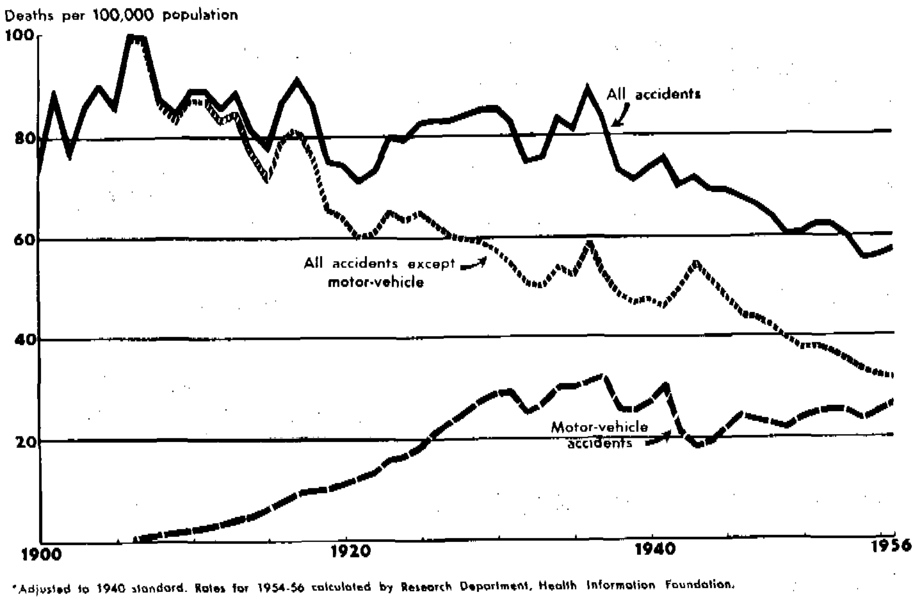

CHART I. Mortality from accidents by principal class, United States (death-registration states only 1900-1932), 1900-1956.

[*Progress in Health Services*, 6:8:1-6, October 1957. New York: Health Information Foundation.]

manent impairment.† In dollars, total accident costs (including property damage, wage losses because of inability to work, etc.) were estimated at about $11.2 billion—almost as much as Americans spend for all private medical services.

Accidents occur in four kinds of environments—on the job, in public places, at home, and in motor vehicles. In the last 30 years, accidents on the job and in public places have decreased substantially, but those involving motor vehicles have increased as the volume of motor traffic has expanded.

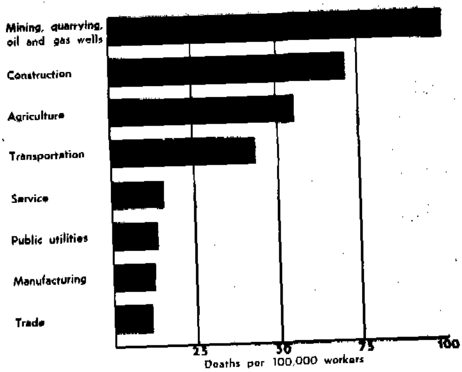

CHART II. Mortality in work accidents by industry group, United States, 1956.

On-the-job Accidents

One of the brightest elements in the entire situation has been the success achieved against fatal accidents on the job ("work" accidents). In spite of a greatly expanded labor force, the death toll of workers on the job has been reduced from 19,000 in 1928—the first year these data became available—to 14,300, as estimated by the National Safety Council for 1956. Death rates in 1956, 23 per 100,000 workers, established a record minimum at just over half the peak rate of 43 in 1937.

The most hazardous industries in 1956 were mines and other extractive industries, where the mortality rate reached 100 per 100,000 workers (see Chart II). The construction industry followed with a rate nearly three-fourths as high, 71 deaths per 100,000 workers. The safest industries were trade, manufacturing, public utilities, and services with mortality below the national average.

Much of the success against work accidents has been due to intensive safety campaigns, resulting in increased safety consciousness among both employers and employees, and to improvements in conditions at work and in levels of living and of medical care. Protective devices have been adopted against the major accident and health hazards in industry, including high temperature, silica dust, radiation, and toxic chemicals. Shorter working hours have helped to cut industrial fatigue, so often a factor in accidents. In many industrial processes the replacement of noxious substances by harmless ones, and the substitution of automatic machinery with proper safety devices for hazardous manual techniques, have helped considerably to reduce the accident toll.

Recreation, Public Transportation

Also encouraging is the substantial reduction in mortality from public accidents, i.e., non-motor-vehicle accidents occurring in public places. Moreover, this reduction has taken place in spite of the increased amount of leisure time enjoyed by the American people in recent years, with much of it devoted to sports and other recreational activities in public places. Deaths from these accidents numbered about 21,000 in 1928 but dropped to 16,000 by 1956.

About a fourth of these deaths—4,000 in 1956—were due to the drowning of persons while swimming or playing in water or falling into water. If drownings in transportation or boat accidents are included, the total exceeds 5,000. Falls and firearms combined accounted for an additional fourth of the public-accident death toll in 1956.

Almost an additional fourth—3,650 in 1956—involved some form of transportation, primarily air, water, and railroad.

† National Safety Council, "Accident Facts—1957 Edition," and various prior issues. Many of the data in this bulletin are derived from this source.

The largest toll—1,300 in 1956—came from aircraft accidents, both military and civilian. In view of the huge increase over the last few years in the volume of air traffic, this figure, although high, is still a considerable improvement over former years.

The largest number of fatal aviation accidents usually occurs in private flying, chiefly for pleasure and other noncommercial purposes. Domestic scheduled airlines have a superior record. In no year since the 1933-37 period has the death toll on scheduled airlines exceeded 200, and in only four years—1947, 1951, 1955, and 1956—has it exceeded even 100. Over the last 20 years the average annual death rate per 100 million passenger miles on these carriers was cut by over 90 per cent, from 7.80 in 1933-37 to 0.62 in 1956.

Just as heartening a story can be told about progress in railroad safety. Of the major forms of transportation, railroad passenger trains currently provide one of the safest means of passage, 0.20 deaths per 100 million passenger miles. Deaths in all types of railway accidents (not merely those directly involving the transportation of passengers) have declined sharply, from about 10,000 in 1918 to 2,600 in 1956. Since 1918, deaths of passengers have declined by more than 85 per cent, from over 500 in 1918 to 62 in 1956.

Accidents in the Home

In the home the record has been less promising. With minor fluctuations, the number of deaths from home accidents has averaged around 30,000 each year since 1928; in 1956 the total was 28,000. Thus the American home was involved in nearly 30 per cent of all accidental deaths in 1956.

About half—13,600 in 1956—resulted from falls (see Chart III), primarily to persons aged 65 and over. Older people are especially vulnerable because of the greater amount of time they spend in the home and their frequently impaired physical condition.

Fatal burns from fires, and other deaths associated with fire, took over 5,000 lives in the home during 1956. Fire accidents are an important cause of death at all ages and are the leading cause of accidental death in the home at ages 1 through 64. Aged persons and children under five have the highest mortality rates and constitute half the victims in this type of accident.

A large proportion of the victims are trapped in homes destroyed by fire. Important among causes of death by burns in the home are careless smoking, accidental igniting of clothing on a stove or open fireplace, and explosion of cooking or heating appliances. In the past few years deaths have declined considerably as a result of general modernization of homes and widespread use of improved facilities for cooking, heating, lighting, and laundering.

About 850 deaths in the home were reported in 1956 as due to poisonous gas. Poisonings by solid or liquid substances accounted for an additional 1,050 deaths.

Motor-vehicle Accidents

Accidents involving motor vehicles took over 40,000 lives in 1956, the largest number ever recorded. Deaths rose steadily early in the century from a low start at 400, the annual average for 1903-07, and

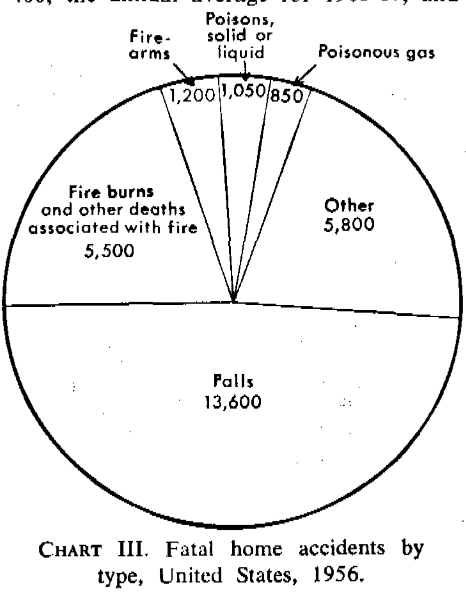

Chart III. Fatal home accidents by type, United States, 1956.

by 1937 and 1941 peaks of just under 40,000 deaths were reached (see Chart IV). Temporary declines during World War II were reversed by a sharp rise afterward. Except for a minor dip during 1954, the course of the death toll since 1950 has been steadily upward.

The rising number of deaths alone, however, tells only part of the story. Since 1900 the U.S. population has more than doubled, and so the death rate per 100,000 persons is a better measure of risk. This rate, like the number of deaths, reached peaks in 1931, 1937, and 1941 (28.3, 31.2, and 29.8, respectively). After declines during World War II, the rate climbed slowly, reaching 25.7 in 1956—still under the former high levels.

The recent increases in the population death rate are not surprising, in view of the growing importance of motor vehicles in American life. While just over 4,000 motor vehicles were produced in this country during 1900, over 9 million were turned out in 1955 alone. In 1956, 64.5 million motor vehicles were registered, while about 77 million drivers were licensed. Moreover, mileage traveled has increased at an almost phenomenal rate. Preliminary estimates indicate that motor vehicles traveled 630 billion miles in 1956, an average of just under 10,000 miles per vehicle.

As a result, a more realistic measure of motor-vehicle risk is the death rate per 100 million vehicle miles. This rate declined consistently, from a peak of 16.7 in 1934, to a record low of 6.3 in 1954. There was a slight rise to 6.4 in 1955 and 1956. This index suggests that safety in motor-vehicle travel has actually increased substantially since early in the century.

The greatest achievement has been the reduction in pedestrian deaths since 1937. From 1927 to 1937 these deaths rose from just under 11,000 to 15,500 but decreased thereafter, especially during the war. By 1956 the number stood at just under 8,000. Pedestrian death rates are lowest at ages 15-44, somewhat higher at ages under 15, and highest at 45 and over. In this last age group, nearly 5,000 such deaths occurred in 1956—three-fifths of the total.

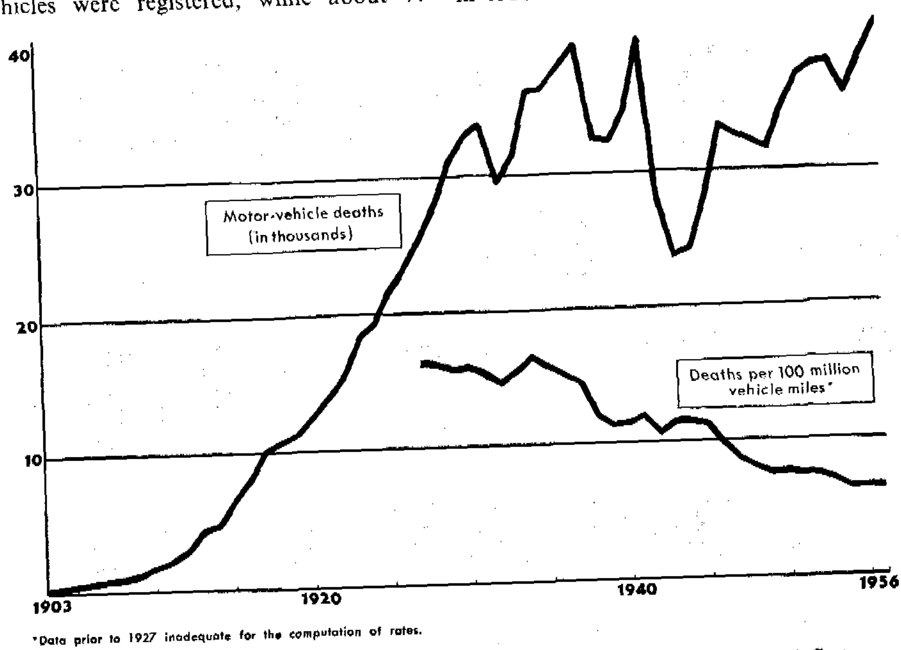

CHART IV. Motor-vehicle deaths, annual number and mileage rates, United States, 1903-1956.

Noncollision Accidents

A rising trend of deaths in noncollision accidents has largely offset the decrease in the number of pedestrian fatalities. The annual death toll in noncollision accidents averaged just under 9,000 from 1927 thru 1941, dropped to about 6,000 during the war years, and since then has risen steadily and rapidly, reaching 14,650 in 1956.

Rising even more sharply has been the toll from collisions between motor vehicles. Deaths in 1956—13,850—were four times as numerous as those in 1927. Here, as with fatal noncollision accidents, persons in the age group 15-24 were the chief victims, and an overwhelming proportion of the accidents occurred in rural areas.

Death rates from all types of motor-vehicle accidents are higher in rural than in urban areas. On the basis of motor-vehicle traffic deaths per 100 million vehicle miles in 1956, three predominantly rural states—Arizona, Alabama, and New Mexico—led the country with rates of 10.1, 9.2, and 9.1, respectively. When traffic deaths per 100,000 population are considered, Nevada, Wyoming, and New Mexico registered the highest rates, 56, 54, and 49, respectively. The New England and Middle Atlantic states, more heavily urbanized, uniformly had the lowest rates by either measure. Among the states, Rhode Island pointed the way with lowest rates of 2.3 and 8.2, respectively.

A recent investigation into one aspect of the motor-vehicle accident problem, violations by drivers in fatal accidents, showed that nearly one-third were exceeding the speed limit, or a safe speed, at the time of the accident. In urban areas, violating right-of-way was the next most common condition, while in rural areas failure to keep to the right of the center line followed in importance. In 22 out of 100 fatal accidents, a driver or an adult pedestrian had been drinking: "driving while under the influence of alcohol" was a factor in 7 per cent of all fatal accidents.

The weather was rainy, snowy, or foggy in one out of six fatal accidents, and in nearly as many cases there was some obstruction to the driver's vision. In nearly one out of 12 fatal accidents an unsafe condition was reported in at least one of the vehicles involved, most often unsafe brakes. About one out of 14 drivers had a physical condition—most often they were asleep—that could have been a contributing factor in the accident. About the same proportion of pedestrians in fatal accidents had physical defects.

Over one-fourth of the drivers in fatal accidents were between 18 and 24, and nine out of ten were men. But no valid conclusions can be drawn from these data about the comparative safety records of the different sex and age groups, since the total mileage driven by each is unknown.

In an attempt to reduce the motor-vehicle death toll, automobile manufacturers have begun to build protective mechanisms into their product, such as safety belts, doors that remain closed under impact, flexible steering wheels, dashboards without protrusions and covered with shock-absorbing material, and similar devices. In addition an important step was taken by the directors of the Automobile Manufacturers Association last June when they unanimously agreed to de-emphasize speed and horsepower in the industry's advertising. For such preliminary measures to be intensified, however, the public must be educated to accept and even to demand at least these minimum protections.

In general, safety against accidents has achieved the greatest success where society has been able to bring its organized influence to bear. Safety regulations are stringently enforced in industry, railroads, scheduled air transport, public beaches, and similar environments, with gratifying results.

On the other hand, where the individual himself must assume most of the responsibility for his own safety and in many instances for that of others (in such places as the home and motor vehicle) safety progress has been slower. Although accidents are often beyond human control, a large element of carelessness and irresponsibility is involved in others. Perhaps the only real solution to the accident problem lies in intensified educational activities designed to spread safety consciousness among all parts of the population.

The fundamental purpose of papers of this type is to supply the uninformed reader with a general brief introduction. This purpose precludes great length, attention to detail, and subtlety. It poses the authors with the difficult task of choosing accurate and representative material easily understood by their readers. This becomes especially difficult when, as is often the case, the authors are not themselves intimately familiar with the subject matter involved and, in particular, with the shortcomings of the research they report.

Examples of Inappropriate Conclusions

It is appropriate to point out a few examples of common deficiencies of such general treatments. The first of these is the use of generalizations based upon data known by informed research workers to be faulty. This can be seen in the statement, uncritically reported, that "about one out of 14 drivers had a physical condition—most often they were asleep—that could have been a contributing factor in the accident." As has been pointed out elsewhere,[6, 9] in a large proportion of fatal accidents attributed to such medical episodes there are no adequate post-mortem examinations, no careful searches for mechanical failures, and no surviving witnesses. In addition, in *non*fatal accidents involving cerebral concussion (a common injury), the resulting unconsciousness produces retrograde amnesia for at least the moment of the impact.[10, 11] Many accident victims who experience such an island of memory loss conclude that the accident occurred after they had fallen asleep, a conclusion reached by injured drivers and passengers alike. Some interpret this experience as having involved a "blackout" despite the lack of any evidence that this was actually the case. Finally, the portion of the non-accident-involved driving public with "physical conditions" is probably considerably greater than 1 in 14, and reporting this merely for those in accidents contributes nothing to our understanding of the factors leading up to the occurrence of the accidents. As a result, statements of this type are greatly suspect since they represent conclusions about matters for which adequate methods of data collection have yet to be developed.

This selection provides, also, several examples (which can also be found in the daily press and in the statements of officials and agencies concerned with highway safety) of conclusions based on uncontrolled observations of the characteristics of those in accidents. Thus it states, "A recent investigation into one aspect of the motor-vehicle problem, violations by drivers in fatal accidents, showed that nearly one-third were exceeding the speed limit, or a safe speed, at the time of the accident," and also mentions that violations of traffic regulations were recorded in other such accidents. It states further that "in 22 out of 100 fatal accidents, a driver or an adult pedestrian had been drinking; [and that] 'driving while under the influence of alcohol' was a factor in 7 percent of all fatal accidents." Similarly, the frequencies of given weather conditions and of "unsafe" conditions are described.

Such statements contribute very little unless it is also known whether the cited characteristics of the accident-involved drivers are present to a different extent among those who are not so involved. For example, it may well be that an equal fraction of the noninvolved drivers operating at the times and places of fatal accidents were also exceeding the speed limit and that this characteristic therefore did not discriminate between those involved and those not involved. Such data are also frequently biased because of the penchant of those investigating accidents to conclude that the occurrence of the accident is sufficient evidence that such violations and characteristics were present. Such conclusions are then used circularly to support pre-existing biases.†

This is mentioned to emphasize again the importance of comparing the characteristics of accident cases with the characteristics of the corresponding populations and situations from which they are derived. Selections of the type reproduced here frequently perpetuate such errors. The informed reader, however, can readily identify these, or at least suspect their presence, when no mention is made of the frequency distributions of the same characteristics among appropriate control populations.

Questionable Practice in the Estimation of Injury Rates

This selection illustrates also another very common pitfall in the use of general rates. This is the practice of using a well-supported rate, usually a fatality distribution, as the basis of a second rate derived from it by unsubstantiated assumptions. In the accident field this occurs most commonly in the calculation of injury rates from fatality rates. In the present paper the reader's attention is directed to the National Safety Council estimate of accident injuries as numbering more than 9½ million per year. This figure is placed in somewhat different light if one considers the following statement from the 1959 issue of *Accident Facts*, published by the National Safety Council:

> ... Injuries are not reported on a national basis, so the totals shown are approximations based on ratios of disabling injuries to deaths developed from special studies. The totals are the best estimates for the current year; however, they should not be compared with totals shown in previous editions of *Accident Facts* to indicate either year-to-year changes or trends. An exception is the work injury estimates, for which broad representative reporting and long established standardization of disabling injury give reliability to a 5 percent decrease from 1957 to 1958.[13]

Despite this clearly stated admonition, it is very easy for those not familiar with this device to conclude that a remarkable consistency in the ratios between fatal and nonfatal accidents has been observed from year to year. Unfortunately, it is not known whether this is the case. Despite this, when the resultant estimates are

† Baker has described a portion of the usual course of events succinctly: "... with their very limited scientific training, police tend to name some law violation as the cause, accepting that which is a stereotype for obvious circumstances. For example, rear-end collisions with both cars moving are nearly always 'caused' by following too closely even when the rear driver fell asleep. These stereotypes may obscure real combinations of contributing factors. In other words, police tend to report common expressions for the symptoms of accidents rather than diagnoses of the causes."[8]

employed, the necessary caveats are seldom retained. This, in turn, serves to hide the poverty of our knowledge of the true state of affairs, to mislead those not familiar with the field except through such sources, and to obscure the need for pertinent research.‡

Cohort Effects

Although the point is not made in this paper, no discussion of the general use and misuse of accident rates can be complete without at least passing reference to the fact that variations in age-specific rates may result exclusively from the characteristics of the cohorts represented rather than from the age of those in the various groups compared. For example, it is common practice to attribute the increased accident rates reported for some groups in the later decades of life to age per se.* There is another possibility, however, which must always be considered whenever trends in age-specific rates are found. For example, the aged pedestrians now walking our streets are members of cohorts that probably had much different experiences with motor vehicles, particularly in their earlier years, than those pedestrians who, in subsequent years, will be of the same ages. The higher accident rates of the former may thus be partially or completely the result of the characteristics of their cohorts rather than the medical, physiological, psychological, and other characteristics to which their increased rates are commonly attributed.

The decrease in total pedestrian deaths referred to in this selection might, as a result, represent the increased experience of successive cohorts of the elderly population at risk with the hazards of an automobile-based society. This is a point which has not been adequately investigated to date and which may also apply to the elderly in many other accident situations. For example, with respect to elderly drivers, restrictions based on the characteristics of groups studied at one point in time might not necessarily be justifiable in connection with subsequent cohorts, a point

‡ The National Health Survey, to date the only scientifically adequate source of accident morbidity data for the entire U.S.A., found such injuries to total 50,098,000 a year (1958-59).[12] The difference between this figure and the approximately 10 million quoted in the foregoing paper, derived from the National Safety Council, has been commonly attributed to differences in the definitions employed:

"Numerical differences in the National Health Survey totals above and the National Safety Council totals . . . are due mainly to differences in definitions, and the inclusion of nonaccidental injuries (such as suicidal and homicidal attempts) in the National Health Survey figures.

"The National Health Survey totals include persons whose injuries caused them to restrict their usual activities for at least a day (including the day of the accident) *or* who had injuries that were medically attended. The National Safety Council totals are smaller since they cover only injuries disabling *beyond* the day of the accident. In addition, the Health Survey figures for motor vehicle (sic) include injuries arising out of nontraffic incidents, such as getting in and out of vehicles, working on vehicles, smashing fingers in doors, etc.

"*The injury estimates of* both *the National Health Survey and the National Safety Council are believed to reflect with reasonable accuracy the injuries meeting their respective definitions.*"[13]

Unfortunately, no scientifically acceptable evidence has yet been published to show whether or not the differences between the totals from the two sources result from the factors cited, and, if so, to what extent.

* For an example of this, see the report of W. Haddon, Jr., *et al.* (Chap. 4) concerned with pedestrian accidents.

that has been almost universally overlooked. This emphasizes once more the need for great care in reaching conclusions through the use of broadly descriptive data not buttressed with the results of investigations of considerably more specific focus. The reader seeking a much more thorough discussion of research concerned with cohorts should consult reference 3.

The Selective Use and Misuse of Gross Rates

Two additional problems inherent in the use of general rates deserve mention. The first is illustrated by what this paper refers to as the "temporary decline [in motor-vehicle accident deaths] during World War II." This is often attributed to the enforcement of lower speed limits and related factors. Although these may well have contributed to this decrease in the gross rates reported, other factors may have been at least partially responsible, and it is not possible by using the general rates alone to determine the extent to which this was the case. For example, there were marked changes in the social and psychological climates in which the risks were taken. Furthermore, new vehicles were scarce at a time when the advertising accompanying their sale had been emphasizing "speed" and "performance" to an extent which may have encouraged their purchasers to use them in ways different from those in which older cars might be driven. In addition, a substantial portion of the young men in the population at risk, the group with the highest accident rates per license holder, was removed from the driving population and hence not available to contribute its share to the accidents summarized in the totals reported. Gas rationing and longer work hours may have modified patterns of use and, finally, there were other outlets available for vicarious or direct resorts to violence. In brief, this is merely one additional illustration of the need for considering all reasonable possibilities rather than merely those consistent with folklore, tradition, or, in some cases, self-interest.

The final illustration, again from the motor-vehicle accident area, concerns the use of tax receipts from sales of gasoline as a basis for the calculation of rates of total vehicle-miles driven. Here again there is no possibility, without studies of more specific focus, of dissecting the variations in quality of exposure that correspond to the use of the gasoline consumed. Also, there is little evidence that estimates of this nature provide a satisfactory denominator for many of the purposes for which the rates so derived are employed, and for some purposes they are obviously unsuitable. Many local and secular factors, including variations in traffic congestion and shifts in driving speeds, in the number of occupants at risk per vehicle,† and in the types of vehicles employed may invalidate the conclusions

† The problem of differences in the number of occupants at risk per vehicle, particularly in accidents of different grades of severity and on highways of different types, arises also in connection with comparisons of the experience of states and countries with substantially different patterns of motor vehicle use. For example, it is unlikely that the frequency distributions of occupants per vehicle under similar conditions of use are completely similar in Western Europe and in the United States. Consequently, the results in injury and death from crashes of similar *physical* severity may vary with the number of occupants at risk as well as with the adequacy of the crash design (see Chap. 9) of the vehicles in use, and this may substantially bias comparisons of this type. Yet death rates per *vehicle-*

reached through the uncritical use of such general rates. Moreover, even if the total miles driven are accurately reported in this fashion, these rates provide no information whatsoever either as to the quality of the exposure represented in such gross terms or as to the factors responsible for the accidents so tersely summarized. Although such rates are employed widely, chiefly to justify action programs undertaken in jurisdictions in which the rates are declining,‡ and in defense of the position that the situation is on the average improving, they have only restricted utility in answering specific questions of the types with which this volume is for the most part concerned. There is, moreover, increasing evidence that their use provides erroneous or misleading answers.*

Although specific problems associated with the use of gross rates inhere in all such general descriptions, it should not be inferred that these serve no useful purpose; they cannot be used safely, however, for reaching conclusions with respect to causation without the support of special studies of the types presented throughout the remainder of this volume.

The Specification of Research Material

Certain characteristics of accidents and of those involved almost always require consideration. The most important are the age and sex of those involved and the time and place of occurrence. In broadly descriptive work these four variables are employed particularly in analyses of age- and sex-specific rates, of time trends, and of differences between groups or areas. In more analytic studies they are used in the definition of the research material employed, particularly in relation to the larger populations from which that material is derived. Despite the importance of these parameters, however, many reports of accident research do not contain adequate information of this type. As a result, it is often impossible to evaluate

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mile driven are widely employed, for example, in arguments that the safety of the American road—especially in its most modern forms—is greater, as may well be the case, than that of its European counterpart. This raises a point well known to sophisticated accident research workers—specifically, that there are many potentially profitable opportunities for cross-cultural research, with respect not only to motor vehicle accidents but also to accidents of other types. Unfortunately, to date there has been little such work.

‡ Unlike the rate per vehicle-mile, which declined for many years prior to 1962, the death rate per 100,000 population has remained quite constant over a long period: 1925, 19.1; 1930, 26.7; 1935, 28.6; 1940, 26.1; 1945, 21.2; 1950, 23.0; 1955, 23.4; 1960, 21.2.[14] (The effects of changes in the method of classification during this period were negligible in this respect.)

* The reader interested in this subject should consult two papers concerned with specific aspects of this problem. The first of these[15] states, in summary, and chiefly from the standpoint of the traffic engineer, that "motor vehicle accident rates with mileage as the risk measure are useful for general safety promotional and educational purposes. Their usefulness for specific engineering and enforcement purposes is quite limited, however, as a result of the gross methods whereby mileage data are collected. Their meaningfulness also is lessened as the distance over which the rate is computed becomes smaller, and in the limit (that is, at a single point) they are completely meaningless. Another weakness of these statistics stems from the fact that the unit of risk is seldom identified with the site of the risk." The second paper[16] documents some of the artifacts that can invalidate conclusions based on data with respect to accidents per vehicle mile. The interested reader should consider this excellent work in the original.

either the soundness of their conclusions or the extent to which they may be extrapolated to other, usually larger, populations.

Additional characteristics which must be detailed with precision involve the accident type and exact circumstances of occurrence, subjects of further discussion in subsequent chapters. For example, it would make little sense to include accidents among non-farmworkers in a study of the role of agricultural machinery; yet many examples of fundamentally similar confusions—most, however, not so obvious—are to be found in the literature.

Many investigators have apparently not recognized the need for care in these respects. Consequently, the findings of such investigations are often useless because of the impossibility of defining the material studied and its relationship to the groups from which it was derived. This is particularly tragic in the many instances in which relatively subtle and expensive tools—various psychometric tests, for example—have been applied to individuals or case series which have been only casually selected and defined.

AN AGE-ANALYSIS OF SOME AGRICULTURAL ACCIDENTS

—H. F. King

In many situations it is not practicable to conduct research that is completely adequate in every respect. This raises the question of whether studies that cannot be models of their types should be initiated and reported. Some would maintain that such efforts tend to delay the completion of more adequate work. Others would hold that as long as the research is done honestly and with the investigators' complete awareness of the deficiencies of both the material and the methods employed, such efforts may produce worth-while contributions.

One of the most common of these situations involves the availability of reasonably adequate data with respect to the accidents to be studied, or with respect to those involved, without correspondingly adequate data with respect to the populations from which these are derived (see Chap. 4). In this context King's contribution illustrates the possibility of deriving at least some information from data which can be subjected only to what are referred to as "internal analyses," without reference to the corresponding characteristics of the entire population at risk.

REPORTS ON INVESTIGATIONS into age variation in accident rates among industrial workers have usually presented data showing overall frequencies of accidents for a department, a factory, or an even wider area. Apart from difficulties which arise through inadequate control of exposure to risk, such data are of little assistance as a guide to practical measures of accident prevention, since no account is taken of age differences in kinds of liability. In this study an analysis was made of nearly 2,000 accidents to workers in agriculture, where there is a wide range of tasks and situations,

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and a corresponding variety of kinds of accident, to see whether age differences could be established. The results indicated that the prevalent kinds of accidents varied with age, significant differences being found for accident causes, the nature of injury, and the part of the body injured.

The Problem

During the last thirty years there have been a number of studies of occupational accident rates in relation to age, most of which have led to the conclusion that as workers become older they become less liable to accidents. Careful examination of the relevant articles shows that as a rule insufficient allowance has been made for the operation of important influences such as selection of workers over the years, experience outside the factory under study, and differences in age between the population on one kind of work and that on another. In addition, the overall rates of accidents in departments or in whole factories have been considered without analysis of kinds of accident, location and nature of injury, and the like.

The present state of affairs is no doubt largely due to the inadequacy of the information available, for few sets of data measure up to the requirements listed by Whitfield as necessary for a thorough study of accident causation. However, it has been contended elsewhere that the exact shape of an accident curve for age will vary according to the nature and stresses of the job and the working conditions. If this view is correct, the analysis of a sample of accidents occurring in a number of different situations into separate kinds of accident might be expected to reveal age differences. As a further consequence, it might be possible to indicate situations in which the environmental stresses fall at points where age changes increase older people's risk of injury, or places where their capacities are such as to enable them to avoid the hazards of a job to a greater degree than a young person. Any such results, even if only tentative, would be of value at a time when much emphasis is being placed upon the extension of employment opportunities for older workers.

Where the great majority of accidents in a department are of a similar nature, as was found by Newbold to be the case in the making of tin boxes, to give only one example, it may well be that a result will be obtained which appears to show a definite age trend in accident frequency. In such a case, in the absence of detailed analysis, other trends are likely to be obscured because they are only to be seen in small groups of cases which are outweighted by the predominant group. In a situation where there is the possibility of numerous kinds of accidents, there is a greater chance of observing such trends, provided that the sample is sufficiently large. Agriculture happens to be a place for study where these hopes are fulfilled since, during the course of the farm year, many different techniques are used, and the organisation and conditions of the work provide opportunity for a variety of accidents. While, for reasons which will appear, the records available for agricultural accidents were not ideally suitable, the analysis of them provides evidence for the existence of several different age trends in accident rates rather than a single overall trend.

Source of Data

One of the two trade unions having agricultural members in branches throughout England and Wales supplied details of 1,991 cases of injury incurred by farm workers during the course of their employment. Apart from 127 cases in which injury, usually in the form of strain or synovitis, was not the result of an 'accident' in that it did not have a sudden onset at any particular moment, the sample is made up of injuries through accidents in the strict sense of the term. The cases supplied were those dealt with during the period January 1st to July 31st, 1949. (Since 1949 the number of cases dealt with has increased considerably.) On the basis of total membership figures, at the time about 130,000, it would seem that there were about 2.6 reported accidents per 100 members per year. The necessity for calculating such figures from 7 months' experience arises because the original plan for analysing a whole year's records had to be curtailed, the task of extraction proving to be too heavy for the union's staff.

When a member had received medical attention for an injury received in the course of his employment, he filled in a form giving personal details and information concerning the accident, and could then obtain accident benefit if necessary; in addition, questions of insurance and compensation, if such arose, could be handled by the union. There was no qualifying period of disability before an accident was recorded, and so far as this study was concerned no account was taken of the possibility that a man might have sent in forms for more than one accident during the period. From the records were taken for analysis the particulars relating to the age of workers, the location and nature of injury, and a brief description of the circumstances under which the accident occurred. The following are examples of the extracts received:

AGE	INJURY	CAUSE
52	Bruised shoulder	Fell from load of straw
28	Fractured wrist	Starting tractor
44	Injury to knee	Kicked by cow

There was no information upon the ength of service or of experience, or the nan's occupational designation (the last vould in the case of farm workers have been of only limited value, because of the ariety of tasks and their overlap from one esignation to another), and in a number f cases the reports were not so precise s was desirable. The length of disablement as not a subject of study, but a number f previous workers have shown that ccident severity in terms of time lost rises eadily with age. It will be seen from this escription that the data fell far below c ideal, and analysis and conclusions must be correspondingly limited. We cannot calculate the frequency of accidents by age groups in the population at risk, since the age-structure of the union membership is not known, and it is therefore necessary to work on a basis of internal comparisons within the overall data. However, comparison can be made (Table 1) between the age distribution of the injured persons and that of the insured population in agriculture at July, 1948. The distributions follow roughly the same pattern but the proportion of accidents to workers is relatively small in the under-21 age group, which may be attributable in some measure to low union membership at these ages.

TABLE 1.— AGE DISTRIBUTION OF ALL ACCIDENT CASES AND OF ALL INSURED WORKERS IN AGRICULTURE,* JULY 1948

Age group	*No. of accidents*	*% of total*	*% of all insured workers*
15—20	157	7.9	13.7
21—30	415	20.8	23.2
31—40	469	23.5	22.1
41—50	449	22.6	19.4
51—60	318	16.0	12.6
61—80	183	9.2	9.0
Total	1,991	100	100

* The figures for insured workers were calculated from Ministry of Labour estimates, and exclude employers, workers on their own account, farmers' sons and certain other near relatives, who were at that time not insurable under the Unemployment Insurance Scheme. Men aged 65 and over were also excluded, but an estimate derived from Ministry of Agriculture returns (June 4th, 1948) has been included for this group.

CAUSES OF THE ACCIDENTS

While accident prevention in agriculture is still at a stage where the detection of the points at which mechanical and other hazards exist, and the consideration of what measures should be taken for their removal are of major importance, we are mainly concerned with the human aspect of the problem and the analysis has been framed with this in mind. There are some cases which human capacity could not have foreseen or escaped, but such 'no human factor' cases form only 1 to 2 per cent of the total. Table 2 gives the percentages by age groups of cases falling in various categories of cause, the table being divided

TABLE 2.— CAUSES OF ACCIDENT

Cause	*Number of cases*	*Percentages of each kind of accident by age groups* 15–20	21–30	31–40	41–50	51–60	61–80	*Significance of age trend (P)*[1]
INCREASES WITH AGE								
Falls from heights or machines	252	7.6	8.4	10.5	14.5	19.2	16.4	<.001
Falls through slipping or tripping on ground	201	3.8	6.3	9.4	13.4	11.0	16.4	<.001
Hit by falling or moving object	339	14.0	15.7	13.9	17.6	21.4	21.3	<.004
DECREASES WITH AGE								
Caught in machine	202	13.4	11.8	11.5	9.1	7.9	6.6	<.002
Injury inflicted by own tool	184	13.4	11.8	10.7	5.8	6.6	9.3	<.001
Continued activity	127	4.5	9.2	7.9	6.2	2.8	4.4	<.001
Starting an engine	98	12.7	7.9	4.1	4.5	1.3	1.1	<.001
NO SIGNIFICANT CHANGE WITH AGE								
Moving heavy objects	103	3.2	4.8	6.8	4.2	7.5	1.6	>.1
Knocked against, or trod on, object	90	6.4	3.6	5.3	4.9	3.4	3.8	>.1
Action of animals[2]	79	1.3	3.9	4.3	4.2	5.3	2.7	>.09
Trapped, other than in machine	48	1.3	3.1	1.9	2.7	1.6	3.8	>.1
Miscellaneous	127	9.5	6.0	7.7	4.7	6.0	6.0	—
Cause not specified	141	8.9	7.5	6.0	8.2	6.0	6.6	>.1
Total	1,991	100	100	100	100	100	100	

1 The test for significance used was Whitfield's modification of the *Tau* method of rank correlation, whereby the total number of cases was divided into those of a given type and those not of that type, followed by ranking into 5-year age groups. In this table, however, for conciseness the proportions are given by 10-year age groups. All ages over 60 were taken as one group.

2 Some cases in which animals were involved were classified under 'hit by falling or moving object.' This group constitutes the remainder.

into sections according to the nature of the age trend. There was a sizeable number of cases in which the description was too vague for them to be classified, but this group does not show any age bias. A number of groups of causes, each with less than 40 cases, and thus too small for satisfactory treatment, have been placed together in the table.

The groups of causes which are seen to be particularly prevalent among the older persons correspond to those listed in the report of the National Advisory Committee on the Employment of Older Persons as kinds of accident to which older industrial workers are more liable than younger ones. Also mentioned in that report were injuries from works transport, but very few cases of this kind occurred among the agricultural accidents. Sheldon and Droller have independently found a high incidence of tendencies to fall among elderly persons whom they visited, but it is interesting to note that the increase here observed in such accidents begins at ages far below the lower limits of their samples. Droller considers that involutionary changes in the central nervous system are ultimately responsible for the trend, leading to slowness in recognising the hazard, in deciding what action to take, or in organising and executing the muscular response. Such slowness is in line with what is known of sensori-motor performance by older people in general, and could also account for the increase with age in accidents due to being hit by a falling or moving object. If this is true, sensori-motor slowness, whatever its ultimate cause might be, could account for all the categories of accident which show a significant rise with age.

The kinds of accident so far considered occurred in a wide variety of situations and during the execution of many kinds of task so that it was reasonable to regard the trends as being in fact due to increased liability with age, rather than to special environmental factors. So far as the decreases with age are concerned, it is less easy to eliminate the influence of variation in the age distributions of men on different kinds of work. Tractor drivers have a relatively high exposure to risk of 'starting an engine' and 'caught in machine' accidents, and workers of this kind are mainly younger men. This may not be the only factor, however, since accidents of both these kinds can be greatly reduced in frequency if sufficient care is taken and use is made of precautionary measures. Increased experience in general, and a refinement of skill in the use of the tools, in addition to greater care, are the probable explanations of the decrease with age in accidents due to mishaps with hand tools. The same appears to be true for 'continued activity' injuries, incurred through the repetition of a task to an extent to which the part of the body concerned was not accustomed, or through failure to throw the load on the right muscle groups. In these last two categories it is improbable that the observed trends can be accounted for in terms of differences in age distribution of men on various types of work, because of the widespread occurrence of the tasks involved.

The absence of age variation in the incidence of injuries arising during the lifting or moving of heavy objects is interesting, since strength as measured by a variety of tests has been shown to decline with age from the late 20's onward. If older people were avoiding the heaviest jobs to a substantial extent, in a way similar to that observed by Richardson among workers in heavy industry, one might expect a decrease with age in injuries of this kind. On the other hand, if older men carry on doing the heavy jobs while finding them difficult it would be expected that there would be an increase with age in these accidents. It is possible that both factors are in operation and are more or less balancing.

Part of Body Injured

Analysis of the sample according to the location of injury again reveals strong age trends, particularly a decrease with age in the proportion of arm injuries, which form the largest group. The figures are given in Table 3. Injuries to the trunk skeleton and musculature increase markedly with age, and leg injuries do so to a lesser extent. Falls predominated among the causes of trunk injuries, accounting for 182 cases, and were particularly numerous at the upper end of the age scale. For arm injuries, several groups of cause were of major importance; namely, caught in machine (161 cases), injured by own tool (135), hit by object (90), and starting an engine (74).

Table 3.— Location of Injury

Location	*Number of cases*	*Percentages of each region of injury by age groups* 15–20	21–30	31–40	41–50	51–60	61–80	*Significance of age trend (P)*[1]
(I)NCREASE WITH AGE								
Trunk, skeleton and muscles	406	10.0	12.2	20.9	22.4	27.5	22.9	<.001
Leg	560	24.4	23.9	28.1	28.6	26.3	34.0	<.04
(D)ECREASE WITH AGE								
Arm	814	53.8	51.2	38.8	33.8	31.7	31.9	<.001
(N)O SIGNIFICANT CHANGE WITH AGE								
Head and neck	92	5.6	4.7	3.7	4.3	5.5	3.7	>.1
Eye	66	3.1	2.8	2.7	3.7	3.9	3.2	>.1
Trunk, internal organs	65	2.5	2.6	3.3	3.9	3.0	3.2	>.1
Region not stated	48	0.6	2.6	2.5	3.3	2.1	1.1	>.1
Total[2]	2,051	100	100	100	100	100	100	

[1] The method of statistical analysis was the same as for accident causes.
[2] The total here exceeds 1,991 because a few accidents caused injury to more than one region.

The first two categories predominated among cases of injury to fingers and thumbs, accounting for 209 of the 370 cases; the last accounted for 44 of the 133 wrist injuries, where falls and continued activity were also important. Injuries to the hand and to the arm above the wrist were less dependent on any single group of causes. Falls accounted for 31 per cent, and hits by objects for 29 per cent, of the leg injuries, and their effect was seen when the region was subdivided, although with some differences in relative importance. Thus, falls caused twice as many knee and ankle injuries as did hits by objects, while the reverse was true for foot cases, and nearly so for the other parts of the leg.

It is clear that there is often a strong relationship between the type of accident and the part of the body likely to suffer. In general, the kind of accidents which young people incurred tended to be connected with the job in hand and to result in the injury of the member concerned. The kinds of accident to which the older people were particularly liable, falls and hits by objects, frequently resulted in injury to parts of the body not directly involved in the activity preceding the accident.

Type of Injury

While up to this point there has been little previous work to compare with the present results, there have been some studies of age and type of injury through accident which provide a useful check on the findings. The figures for various kinds of injuries are given in Table 4, where it will be seen that a difficulty encountered during the analysis was the existence of a considerable number (641) of cases where only the words 'injury to . . .' appeared in the accident report. It was found that as age increased, so did the likelihood of such a vague report.

The decrease with age in the frequency of cuts and lacerations, and also the similar tendency observed for the small number of burns and scalds, where 17 of the 20 cases occurred among men under 40 years of age, is in agreement with that found by Barkin among a group of males compensated for temporary disability. Stevens' figures on age and length of disability among 5,000 compensation cases, when used to calculate proportions by age groups, give the same result. Barkin suggested that the decrease in cuts and lacerations was due to the fact that "the older individual masters his tools and becomes more proficient and careful at the job." Among the agricultural cases, 80 per cent of the injuries caused by faulty manipulation of a tool were cuts and lacerations, forming 45 per cent of all injuries of that kind.

The other investigators' results also show a decline with age in the proportion of punctures, but these would have been in the main inflicted by tools, whereas among agricultural accidents many were caused by thorns, and arose very differently. Barkin's figures for fractures show a general upward trend with age, but in our data the highest proportion occurred in the 15–20 age group, followed by a fall to the minimum in the 31-35 group, with some tendency to rise thereafter. No groups of causes predominated, so that it is difficult to suggest reasons for the differences in the results. However, it is interesting to note that Padley, in a study of injuries to Scottish insured workers, did not find an increase with age in fractures among men, although he did so among women.

Bruises formed 36 per cent of the injuries in Barkin's sample, against 5 per cent here, but in both instances an increase with age was observed. The existence of the large group of 'injury cases' may partly account for the large difference in proportions, since it seems reasonable to assume that many of these were in fact bruises or contusions where the disability is of a less definite kind than it is for, say, a fracture or a cut. For both the groups of 'injuries' and of bruises and contusions, falls were the largest group of causes, followed by hits by objects, the two kinds together accounting for more than half the cases.

The analysis of type of injury, although insufficient to provide more than pointers to the reasons for the observed trends, aga

TABLE 4.— NATURE OF INJURY

Injury	*Number of cases*	*Percentages of each kind of injury by age groups* 15–20	21–30	31–40	41–50	51–60	61–80	*Significance of age trend* (P)[1]
INCREASE WITH AGE								
'Injuries'	641	25.0	28.0	29.6	36.0	34.9	34.9	$<.001$
Bruises and contusions	112	4.4	3.3	5.9	6.4	5.8	8.2	$<.02$
DECREASE WITH AGE								
Cuts and lacerations	334	22.5	20.9	16.0	11.8	15.3	16.4	$<.001$
Crushings	99	5.6	6.6	4.6	4.8	4.3	2.2	$<.02$
NO SIGNIFICANT CHANGE WITH AGE								
Fractures	309	19.4	15.6	12.4	14.3	18.3	15.3	$>.1$
Sprains and strains	223	7.5	10.0	13.0	12.9	8.9	10.4	$>.1$
Punctures	133	7.5	5.9	8.6	5.5	5.8	6.0	$>.1$
Hernia	53	1.9	2.4	2.1	3.3	2.7	3.3	$>.1$
Miscellaneous	120	6.2	7.3	7.8	5.0	4.0	3.3	—
Total[2]	2,024	100	100	100	100	100	100	

[1] The method of statistical analysis was the same as for accident causes.
[2] The total exceeds the number of accidents because in a few instances more than one injury was incurred.

shows that accident trends with age may differ markedly according to the nature of the accident considered.

CONCLUSION

Previous studies of accidents in industry have given results which are either conflicting or are liable to misinterpretation because no proper account has been taken of different exposures to risk of older and younger people. The collection of data from which the influences of variable exposure to risk can be completely or even largely removed presents very considerable difficulty and could not be attempted here. On the other hand, practical measures to prevent accidents should take into account the actual accidents sustained, their causes, their nature, and the parts of the body injured. In so far as these differ with age different measures of accident prevention are needed for younger and older persons. However, the overall accident statistics which are usually presented give no indication as to whether the causes and nature of the accidents differ with age. While suffering from a number of limitations, the present data indicate that they do, whichever criterion one adopts, cause, nature of injury, or part of the body injured.

King is able to show, in this paper, considerable differences in the age distributions of those involved in agricultural accidents of various types—differences that were obscured until the several types were studied individually. He recognizes that the data employed "fell far below the ideal, and [that the] analysis and conclusions [had to be] correspondingly limited." He adds, "We cannot calculate the frequency of accidents by age groups in the population at risk, since the age-structure of [that population] is not known, and it is therefore necessary to work on a basis of internal comparisons [*sic*] within the overall data." He states further, in his conclusion, "The collection of data from which the influences of variable exposure to risk can be completely or even largely removed presents very considerable difficulty and could not be attempted. . . ." Nonetheless, although his work is based almost entirely on internal comparisons, it does contribute additional understanding of the nature of those accidents and of the directions in which further research might move.

At the same time it is hazardous to conclude, except in a descriptive rather than a causal sense, that " . . . the causes and nature of the accidents differ with age." It is entirely possible that the differences in the accident type-age distributions observed resulted entirely from qualitative and quantitative differences with age in exposure to risk. This serves, then, as an additional illustration of the need to relate the circumstances of accidents and the characteristics of those involved to the characteristics of the periods and places in which they occur and to those of the populations from which they are derived.

TRAUMATIC ACCIDENTS IN RURAL TROPICAL REGIONS: AN EPIDEMIOLOGICAL FIELD STUDY IN PUNJAB, INDIA

—John E. Gordon, M.D., Prem V. Gulati, M.B., John B. Wyon, M.B.

The next selection is an excellent example of descriptive epidemiology employed to assess the general nature and magnitude of the accident problem in a group of rural villages in the Punjab. Although numerous papers might serve as examples here, this one has been chosen because it represents an unusual combination of excellence of method and presentation with uniqueness of subject matter.

Descriptive investigations often fall into one of two categories. The first of these uses data collected by others, usually for other purposes. The second, illustrated by this paper, uses data collected by the responsible investigators. In general, granting equal levels of competence in both categories, the latter is usually freer from the biases and shortcomings that result from the inability of the investigator to control the quality of the data used. Nonetheless, in many situations, particularly those involving the distributions of accidents occurring in very large populations, it is not possible for individual investigators to undertake both the collection and the analysis of the data.

The contribution by Gordon and his colleagues begins with a detailed and competent discussion of the need for studying accidents in rural, pre-industrial societies rather than devoting exclusive attention to those occurring in urban, Western societies. This is amply buttressed by the data, which demonstrate the remarkably high rank of this source of morbidity in the villages studied. In view of the clarity of the presentation, it is perhaps superfluous to point out that the methods, as must always be the case, were carefully tailored to the nature of the society and the culture in which the study was undertaken. This required som modification of definitions commonly employed, and it involved a number o unique features—for example, the use of caste membership as the basis of a socio economic classification. This paper will undoubtedly become a classic and shoul point the way to investigations in many similar areas in Asia and elsewhere.

The prevention and control of accidents is a recently recognized part of official public health activities. For years th compelling demands of the epidemic d

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seases overshadowed other matters of community health, with the result that public health gave little attention to the deaths and disability associated with accidental traumatic injury. Within the past decade or so, the United States and Canada have greatly expanded their previous efforts and a similar development is also evident in Europe and in other countries with well developed health services. The World Health Organization has promoted accident prevention as an integral part of public health programs in developing countries.

The chief emphasis has been on accidents in metropolitan communities, especially the injuries traceable to motor vehicles. Accidental injuries among rural residents have had much less attention. The situation in the Arctic and in the tropics is little explored. No study is known of accidental traumatic injury in a rural tropical region, although in the tropics many more people live on the land than in cities. This review includes the report of a field study in villages of the Punjab, India.

Practicing physicians always have distinguished disease from injury, and in so doing have subscribed to the dual obligation of caring for both the sick and the injured. Preventive medicine in its beginning was concerned almost wholly with disease. It was thus no surprise that the origin of a community responsibility for accidental injury was with the medical profession rather than public health, and likewise that the emphasis was more on medical care than on prevention. As so often happens, attention first centered on the unusual and dramatic misfortunes that affect large groups of people, the catastrophes associated with hurricanes, floods and fires. The first organized effort was by the American National Red Cross in the Michigan forest fires of 1881, and relief of distress was as much a consideration as medical care.

Realization came much later that the fundamental question is with the accidents that occur in the course of everyday living, at work or at play. In 1903 the American Medical Association became actively concerned about the burns and other mishaps then so frequent as a result of the uncontrolled and common use of fireworks in celebration of American Independence Day. The current interest in poison centers, primarily in relation to children, had its beginning in 1910; it came from the pitiful results following ingestion of lye, at that time a common household commodity. These activities introduced the concept of prevention: namely, an understanding that accidents have definite causes that are as susceptible to administrative and medical management as those of many diseases.

As motor cars progressively supplanted horses, an important new element was introduced. The United States Government through Secretary of Commerce Hoover called a conference on street and highway safety in 1924. The discussions had a result beyond the immediate objective; attention was directed to the broader question of accidents in the home, in industry and in public places other than highways. The initial leadership in prevention and control was thus from welfare, police and other local governmental authority and from industry. Various agencies of the national government took part, as did voluntary agencies, notably the National Safety Council.

Accidents as a Public Health Problem

Appreciation that official public health departments had a responsibility in accident prevention was of slower evolution. The first move was by a health officer in Kansas. The early attention to industrial accidents and the initial emphasis on social and economic aspects would suggest that a public health approach to accidents was more likely to have developed through action in a metropolitan community or in a center for public health research. The advantage that Earle Brown had in Kansas was a familiarity with the health needs of an everyday American community, and he correctly appraised the rank of accidents among leading causes of death. For several years his effort was a more or less one-man crusade for acceptance of the principle that accidental injuries have specific causes and that preventive measures directed to those causes are practical and reasonable. The interest spread.

When the Association for State and Territorial Health Officers met in 1941, motor accidents had a prominent place on the agenda, but much time also was devoted to the home and other forms of accidental injury that occur in the more ordinary course of life. Since 1942, the American Public Health Association has stressed home accidents as a part of the official responsibility for health. The then current war inhibited an otherwise certain extension of effort. However, the movement had subsequent and important impetus from two events directly connected with war-time experience.

The first circumstance was the impressive demonstration that disease no longer dominates the casualties of war. The ratio of deaths from disease to deaths for battle casualties for the wars of the 18th and 19th centuries was sometimes as great as 13 to 1. In every American war until 1941 disease caused the most deaths, although the A.E.F. in World War I had fewer disease than battle deaths. World War II brought a complete reversal. Deaths from battle casualties were 15 times greater than deaths from disease, and at the same time battle casualties were at a lower rate than in 1917. Still more striking, and for the first time in American military history, the fatalities from non-battle injuries, essentially deaths from accidental injury, also exceeded deaths from disease and in a proportion of 4 to 1. Accidents thereby took on new significance among military disabilities and by inference as a cause of death of young adults.

The second contribution from war-time experience was a method of study that put accident control on a sounder basis. During the winter of 1944–45 some 44,228 cases of trench foot or cold injury, ground type occurred in the European Theater of Operations. That circumstance gave opportunity to test the methods of field epidemiology in assessment of the epidemic, in identification of responsible causes and the development of methods for prevention and control. Epidemiologic analysis proved to be as useful in injuries as in disease. The result was a definition of principle for investigation of accidents under civilian conditions. The technical procedures were tested in a subsequent study of home accidents.

The years since then have seen a remarkable increase in the effort and resources directed to control of accidents. Most state health departments now have organized divisions for the control of traumatic injuries, and likewise the larger municipalities. An inventory of what has been accomplished by medicine and public health and by numerous other agencies of society is outside the scope of this paper. The decline in specific death rates for accidents of all forms is sufficiently informative. In 1945 the annual mortality from accidents in the United States was 72.4 per 100,000 population; in 1960 the rate was 51.7. The result is impressive, but it needs to be, because accidents are still the first cause of death at all ages from 1 to 36 years; and for the whole life-span of the population, the fourth leading cause.

The enlarged operational endeavor had the usual result of exhausting facts essential to further effective action. Consequently, research on causes and control procedures has developed remarkably and from a variety of sources. The universities have taken a prominent part through schools of medicine and of public health; studies by health departments are numerous, and commonly directed toward operational needs. A special commission of the Armed Forces Epidemiological Board has responsibility for military needs. Through grants in aid, the United States Public Health Service liberally supports activities in public health practice, in research and in teaching. It has within its organization a Division of Accident Prevention under the charge of an Assistant Surgeon General and is active in a research program of its own.

A decade or so ago, accidents were an uncommon feature of instruction in preventive medicine and public health. Today all American schools of public health present the subject through lecture, seminar or epidemiologic laboratory exercise. A recent survey of 83 departments of preventive medicine in medical schools showed that 68 included accident control in their curriculum.

World-wide Occurrence

Injuries from accidental trauma occur everywhere, in all times, in all places and among all persons. Many diseases have as universal a distribution geographically, cryptococcosis, for example, but cases are rare. Some few also occur in comparable numbers, the common cold, but with essentially no fatality. A still smaller number have death rates of equal or greater magnitude and occur just as widely but with cases concentrated at special ages, cancer and heart disease for instance. Traumatic injuries have an additional characteristic in the residual crippling they produce.

Whether judged by deaths, by permanent residual defect or resulting days of disability, accidents impinge strongly on human health and welfare. The diarrheas and the dysenteries are a close rival and yet evidence a selectivity in kinds of persons attacked and in places of occurrence. There is perhaps justification for the attitude of some primitive societies that the two natural causes of death are old age and violence, and all else is magic.

Annual reports to the United Nations show the consistent occurrence of deaths by accident in all regions. For 68 countries isted in the 1959 Demographic Yearbook, annual rates ranged from low values of 6.4 per 100,000 population in Sarawak and 5.9 in the Dominican Republic, island ations with data recognized as unreliable, o a maximum of 69.9 for Austria. The ates are not comparable because of ifferences in classification, variation in ompleteness of reporting and divergent olicies about what to include.

Countries of temperate regions with a favorable economy have relatively high rates. The mechanization of industry and of life in general, the important factor of motor traffic fatalities and an increased frequency of poisonings are contributing influences. Accidental deaths are better recorded; they also take on greater relative significance as other community diseases come under control, notably the infectious diseases. Rates in the United States in 1957 were 55.9 per 100,000 population; and with suicide and homicide added, deaths by violence totalled 70.2. In Europe, accident rates for representative nations were 37.5 in England and Wales, 58.6 in France, and 38.8 in Sweden; they were 38.7 in Japan and 51.6 in Australia.

The nature of the physical environment and the exacting demands of life in cold climates make accidents unusually frequent in the Arctic. Traumatic injury of accidental origin is the first cause of death in Greenland, having recently superseded tuberculosis; and the same holds for Alaska where the rate is 107.4. The specific nature of the accident problem has not been studied in detail in any arctic region despite its evident importance.

The accident situation in the tropics is almost as indefinite as in the Arctic. Most reported death rates are admittedly unreliable, chiefly because they are many times derived from urban data and hospital statistics. The cited rates for representative countries are of the same general magnitude as those for North American and European nations; Burma for instance has a mortality of 59.1 per 100,000 population, Nigeria 38.0 and British Guiana 44.5, despite in each instance a minor contribution from motor vehicle accidents. The inference is that accidents due to other causes are materially higher in those countries than in North America or Europe.

Kinds of Accidents

The usual classification of accidents is by place of occurrence, with division into those occurring at work, at home and in public places. Motor vehicle mishaps, although they are accidents in public places, are put arbitrarily in a fourth and separate category because of their numerical importance.

Motor vehicle accidents were the main consideration among 92,080 deaths from accidental injury in the United States in 1959, as they have been for the past 12 years. In 1960, 35,200 deaths were attributed to this cause. Although the numbers of deaths continue at a fairly steady level, the rates for this cause have improved with much regularity over a period of 25 years, provided deaths are based on numbers of miles driven or on numbers of registered motor cars, both of which have increased at a greater rate than population. The risks per person are greater and yet the record is better. For example, deaths per 10,000 registered motor vehicles per year were 15.9 in 1945 and 5.3 in 1960. Death rates per unit of population reflected the situation less satisfactorily; they were 28.6 per 100,000 in 1935 and 21.2 in 1960. This factor of injury by motor car is a principal difference in the nature of accidental deaths in pre-industrial and primarily agricultural countries, compared with nations of the western world.

Home accidents have long been a close second in the United States as a cause of death by injury. During the war years of 1942 to 1945 and immediately thereafter they occupied first place because of the curtailment of motor traffic. In 1960 home accidents were responsible for an estimated 27,500 deaths in the United States. In tropical regions, and especially in rural areas, they are presumably the major consideration.

Accidents in public places are a diverse group because of the variety of conditions under which they occur. They are the everyday accidents in public buildings, on the streets and roads, and in spectator crowds at sports and other community assemblies. All accidents associated with travel and transportation are in this group, other than motor vehicle. They include accidents in sports and other recreational activities, notably hunting and swimming. Major catastrophes with multiple deaths in a single accident as in hurricanes, theater fires and floods are a special feature. As a group, accidents in public places ordinarily rank third among the four classes of accidental injuries. In the United States in 1960, the total was 16,500, about half the number of motor vehicle accidents. Primarily, these are the accidents of a sophisticated society.

Popular opinion often restricts accidents at work to events associated with heavy industry; with manufacturing, mining and the building trades. The concept today is much broader to include workers of any vocation, even microbiologists in laboratories. In recent years, numerous studies have measured the risks in service occupations, in public utilities and especially those of children at school, on the reasonable assumption that acquiring an education is their principal occupation. Such studies have been extended to infants and to preschool children. Still more recent is the gradual appreciation that agriculture is not only a principal industry of the world but has its own peculiar kinds of accidents.

A second common fallacy is that injuries at work constitute the main body of accidental injuries. Industry took early leadership in the prevention and control of accidents, under the influence of legal liability and other economic and social consequences. Control programs, voluntarily undertaken and now in force for many years, have had gratifying results. In the United States fatal accidents at work are fewer than in any other of the four general classes already distinguished, 13,800 in 1960.

Accidents in Rural Areas

The lesser effort expended in accident prevention for rural populations in this and other countries is not because the problem is minimal. The mortality from accidents among farm residents of the United States in 1960 was 55.0 per 100,000 population, a rate appreciably in excess of the 51.7

reported for the country as a whole. Accidents are not reportable to health authorities and only irregularly and partially to other governmental agencies. The data on causes and on distributions by time, place and person essential to a program for prevention are to be had, therefore, only by field survey. This is more difficult, and more expensive in time and money, than similar studies in urban and suburban areas.

The older pattern of farming has slowly given ground. Mechanization has brought changes comparable to those in transportation when motor cars supplanted horses. The health hazards, always more or less individual, have thereby been enlarged, particularly in the domain of safety. Traumatic accidents have changed in character and in numbers. An imposing list of chemicals in the form of fertilizers, insecticides, germination accelerators, mold inhibitors and antibiotics for livestock has introduced new risks in poisoning. Agriculture has become an industry and the occupational group is the largest in the United States.

The general increase in health activities by progressive governments was bound to bring improved health facilities to rural people. The changing character of agriculture with its new risks has quickened that movement. One tangible form is the establishment of Institutes for Agricultural Medicine in this and other countries, concerned with the broad aspects of health in rural populations, and without exception they emphasize the importance of accidents.

As happened with accidents in general, one of the earliest studies of accidental injury in rural regions was in relation to motor vehicles. Powers in New York State investigated automobile accidents in a rural area traversed by a transcontinental highway. The study was concerned more with the influence of the rural environment on these events than with the rural population, although residents of the area naturally were involved. The accidents themselves were injuries incurred off the farm.

The principal gain from these studies was in interest turned directly to accidents associated with farm life. In 1950 and again in 1959 in collaboration with Calandruccio, Powers gave results of a consecutive 20 years experience which has done much to define farm accidents epidemiologically and clinically, and in stimulating investigations by others. Conditions in Kansas have been recorded for many years, starting with the original work by Brown, continuing in annual reports and with recent reviews by Snyder. Case studies of nonfatal accidental injuries among farm workers of Wisconsin compared results with those reported by others. The occupational injuries of farm workers in California were brought together by Latourette with special attention to the risks associated with migratory labor. An increased mechanization on South Dakota farms and a more general availability of electric current were reflected in higher accident rates.

Although studies are few, and several are concerned with special and newly evolved features of farm accidents, the existing information is sufficiently comprehensive to suggest that accidents under rural conditions follow much the same broad pattern as in urban communities. The preliminary results of the Ontario, Canada, study of 7835 accidents among farm residents for the year ending March, 1960, are especially informative. More than 32% occurred in and around farm buildings, and another 20% in the fields. Traffic accidents were responsible for about 21%, with home accidents in about the same proportion, 19%. All of the four general classes were represented. The weighting in frequency of accidental injury appeared to be with injuries at work, followed closely by motor accidents and those in the home. The frequency of accidents in public places is indefinite from available data. Deaths by contrast were predominantly from motor vehicle accidents, 142 of 293, with drowning and swimming, falls and fires the other important precipitating causes. This study, as the results become available, and the current investigations of the Iowa group should provide much needed information on farm accidents under American conditions.

Various studies in other countries are contributing importantly to principle and to an understanding of how varying environmental factors influence incidence. Much has been done in Poland on clinical and epidemiological features, along with the social and economic values involved. Urech in Switzerland has made extensive studies on general farm accidents as distinguished from those primarily related to mechanization. France is another center of investigation. Based on hospital experience, farm accidents in Italy appear to be somewhat less numerous in the past 15 years although generally more serious because of machinery as the common agent; the need for a properly conceived program for prevention is emphasized.

Despite a rising and world-wide appreciation of accidents as a health problem, interest has extended only recently to workers on the land; and that in the more favorably situated parts of the world. The risks are almost unknown in countries where mechanization of agriculture scarcely exists.

Accidents in the Tropics

Few epidemiological studies of accidental trauma have been made in any part of the tropics. The significance of accidents as a cause of death is reflected in the 1959 summary of world causes of death by the United Nations. Deaths from motor vehicle accidents are there distinguished from all other accidents, along with information on suicide and homicide as additional manifestations of death by violence.

As would be expected, reported deaths from motor vehicle accidents vary greatly between tropical countries, first because of differences in numbers of automobiles and other environmental conditions, and secondly because of deficiencies in reporting. Compared with 22.7 per 100,000 population in the United States, Egypt had a motor vehicle accident rate of 0.1, Nicaragua 1.2 and Burma 3.5. The range was through Nigeria, 13.7 for the indigenous population, to a reported rate of 22.6 in Brazil, clearly not representative of the country as a whole.

Death rates for the group of all other accidents, motor vehicle deaths excluded, were regularly high. Again in comparison with the United States rate of 33.2, the frequency in Egypt was 58.3, and in Burma 55.6. Most of the listed tropical countries had rates above the United States level. Nigeria reported 24.3 deaths per 100,000; rates were exceptionally low in the Dominican Republic, 10.5, and in some other island countries. The high death rates for tetanus in many tropical regions further substantiate an appreciable mortality from accidental injury, although tetanus neonatorum is the major consideration.

Venezuela is unusual among tropical countries in having systematically analyzed deaths from accidents in a search for causal relationships and the kinds of people most affected. Gharpure, Jhala and Nair in Bombay, India, studied 21,589 hospital patients admitted because of accidental injury. Males outnumbered females by 6 to 1 and the principal causes of injury were falls, assault, motor vehicle accidents, dog bites, machinery and burns in that order. In a later study deaths by accident were found responsible for 5% of 39,916 registered deaths in Bombay City, with train accidents, burns and automobiles mainly responsible. Except for burns, deaths of males were twice those of females.

Morbidity from accidental injury is little known, except for what may be inferred from deaths. The study of Chakravorti on permanent and temporary disability in representative Indian industries is one of few. Limited information about general populations is to be had from clinic and hospital admissions, perhaps most reliably for children.

Appreciation of accidents as a problem of tropical public health and of preindustrial countries generally is following much the same course as in nations where interest started. The beginning is with industry. A rising rate of transportation accidents then attracts attention. The major factor of home accidents is as yet largely unexplored, as are accidents in public places; evidence from all available sources points to their significance. The prevention and control of accidental injury fits into the scheme for an ecologic approach to tropical public health so thoughtfully presented by Weller.

Accidents in rural regions have been neglected the world over in favor of urban communities. So far as rural tropical regions are concerned, no published information is known; and yet the population of the tropics is primarily rural. An opportunity arose to acquire factual data on the frequency of disabling accidents in a group of north Indian villages, as well as the conditions under which they occurred.

Field Study in Rural India

The accidental injuries in four villages of Ludhiana District, Punjab, North India, were studied during one year beginning March 1, 1959. The investigation was possible because of the purpose it served in a study of population dynamics then underway. The aim of that study was to determine the effect on birth rates of a continuing program for contraception. During 4 years, field workers lived in the villages and visited families at monthly intervals to introduce contraceptive procedures and to gain information on births, deaths and migrations. Two controls were needed.

The first was relatively simple. Concurrently with observations on the test population, births and deaths were recorded for a second similar population of about 4,000 people, by the local persons and officials ordinarily responsible for that obligation, the village watchmen and the midwives of the locality. The only contact between villages and study group was through periodic visits by a staff member to confer with the persons who recorded the information.

The second control was designed to measure in still another population the effect on birth and death rates of the presence of outsiders in the village, who resided there, made home visits on a health matter, and collected information on such features of the biology of reproduction as births, deaths and the behavior of the menstrual cycle. The choice of the particular health matter to serve in the control as the counterpart of contraception was of some moment. It had to be without bias to the primary study and desirably of a nature helpful in establishing the initial rapport essential to gathering such personal information. The choice of accidental injury was a happy solution. The condition is clearly unrelated to contraception, it is of close to universal occurrence and people like to talk about their accidents.

Methods and Materials: The study area had a population of 4,377 persons who lived in four villages, two large and two small, and included 782 families. Farmers in northwest India live in compact villages, typically of winding and irregular rows of houses separated by narrow lanes. The houses are mostly one-story, made of mud bricks or sometimes burnt brick. The roofs are so connected that it is often possible to walk across them to other parts of the village. The lanes are sometimes bricked but more often are simple paths that are passable with difficulty during the rainy season because of the mud. From the village the men go out to work the lands.

Farmers and their families constituted about half the population. Lower caste leather workers who worked at their trade and also as hired laborers for the farms and other needs were next in numbers. The remaining castes, chiefly craftsmen and shopkeepers, were grouped in these studies as "other castes." By economic status, the progression was from farmers to other castes to leather workers.

Animals and men supply the power for agriculture. Simple food choppers for animal feed are about the only machines. Bullocks, water buffalo and camels are used in the fields. Cows, buffalo and less frequently goats provide milk; the little meat in the diet is from goats, chickens and pigs.

The main accident hazards other than animals are drowning and fires. Each village has a central artificial pond, the legendary tank of the Indian countryside. Wells are open and usually bucket-operated; there are numerous canals for irrigation. Much of the cooking is by outdoor fires; stoves inside houses are built of mud. Transportation is almost wholly by bullock cart and bicycle; buses and the railroad are used for the rare long journey. Motor cars are non-existent in the villages, and the dirt roads that are the usual approach preclude much of a risk from that source. Houses are commonly of one room, sometimes two, with a storeroom; they house animals as well, and the life of the family is concentrated in decidedly close quarters.

Three lady health visitors, the counterpart of the public health nurse in western countries, visited each family once a month and recorded on a suitable form the details of disabling accidents of the preceding 30 days. A series of preliminary studies with visits at longer and shorter intervals had demonstrated the practicability of this period. The mother of the family was the usual informant, although the injured person was interviewed and examined whenever possible. Serious accidental injuries coming to attention in the course of village rounds were investigated promptly. A physician of the study group was called if the circumstances were unusual.

The study was of disabling accidents, so recognized and included in the series if the injury was of sufficient seriousness to interfere with ordinary activities or duties during the day of the accident or longer, recovery being eventually complete. Injuries resulting in permanent disability or crippling were a second category, and fatal accidents a third. The Manual of the International Statistical Classification of Diseases, Injuries and Deaths was followed in classifying the nature and origin of injuries, with certain additions and modifications to meet local conditions.

TABLE 1.— DISABLING TRAUMATIC ACCIDENTS; INCIDENCE PER 1000 POPULATION PER YEAR IN 4 PUNJAB VILLAGES, MARCH 1, 1959 TO FEBRUARY 29, 1960, BY SEX

	MALE		FEMALE		TOTAL	
Degree of disability	*Number of accidents*	*Accidents per 1000 population*	*Number of accidents*	*Accidents per 1000 population*	*Number of accidents*	*Accidents per 1000 population*
Fatal	—	—	—	—	—	—
Crippling	10	4.4	12	5.8	22	5.0
Disabling	216	94.2	268	128.7	484	110.6
Total	226	98.5	280	134.4	506	115.6

Incidence of Accidental Injury: The number of disabling traumatic accidents during the year of observation was 506, to give an annual incidence of 115.6 per 1000 population. Table 1 shows that 4.3% resulted in permanent crippling, an incidence of 5.0 per 1000 population per year; the remainder were disabling for at least the day of injury. Usual experience would indicate 2 expected deaths in a population of this size during one year. There were none.

For the series as a whole, accident rates among females exceeded those for males by a third. This is contrary to usual experience. The relationship was by no means regular (Table 2) because rates were higher for boys than for girls among children of ages 0 to 14 years, this being the ordinary expectancy; and they were also higher for elderly men past 60 years of age as contrasted to elderly women. The decided weighting toward females was among young and middle-aged adults, and this in an agrarian society where manual labor by men in the fields presumably should conduce to appreciable numbers of accidents. Some bias is possible, in that the data were collected by women field workers, with the woman of the house the more usual informant. Other studies of this same population have demonstrated, however, the equally unusual circumstance that general death rates were higher for females than males at all ages until past 65 years.

School children had the highest accident rates among the groups listed in Table 2. The risk to preschool children was almost as great. Accidents continued at an appreciably high level throughout the productive years of life, largely because of the contribution by women. The lowest accident rates were among the elderly, although the accidents they had were more serious as shown by age-specific death rates to be cited subsequently.

Although the caste system is far less rigid than in former years, it remains a practical index of social and economic status. The lower caste leather workers, or Chamars, had accident rates of 132.1 per 1000 population per year in this experience, contrasting with 112.3 for the better privileged caste of Jats or landowners. Both groups are active in cultivation of the land. The lowest accident rates, 107.3, were among the group of other castes, of varying social and economic status but averaging an intermediate position. The same predominance of accidents among adult women characterized all three divisions by caste; indeed, with minor variations, the age distribution by caste was the same as for the population as a whole.

Place of Occurrence: The usual classification of accidents by place of occurrence, to give the events occurring at home, in public places, at place of work and in connection with motor vehicles, required some modification to meet Indian village conditions. Home accidents are restricted by definition to injuries within the family dwelling and the immediate premises. The usual practice in the villages is to quarter cattle and other domestic animals within the house itself and occasionally in attached rooms. Both accommodations were considered a part of the home in classification of accidents. Rarely are cattle stabled in buildings wholly distinct from the dwelling.

Table 2.— Disabling Traumatic Accidents, All Forms, and Incidence per 1000 Population per Year in 4 Punjab Villages, March 1, 1959 to February 29, 1960 by Age and Sex

	MALE			FEMALE			TOTAL		
Age, in years	*Population*	*No. of accidents*	*Accidents per 1000 population*	*Population*	*No. of accidents*	*Accidents per 1000 Population*	*Population*	*No. of accidents*	*Accidents per 1000 population*
0–4	345	48	139.1	296	31	104.7	641	79	123.2
5–14	594	81	136.4	526	63	119.8	1120	144	128.6
15–24	410	35	85.4	415	51	122.9	825	86	104.2
25–44	510	33	64.7	505	95	188.1	1015	128	126.1
45–64	323	22	68.1	250	36	144.0	573	58	101.2
65+	112	7	62.5	91	4	44.0	203	11	54.2
Total	2294	226	98.5	2083	280	134.4	4377	506	115.6

Public places were temples, schools, streets, the village shops and other buildings or areas used in common by the community. Following usual practice, work accidents were considered to be those occurring at a place of business or in the course of employment providing the principal means of livelihood. Agricultural injuries dominated all others.

The category of vehicular accidents was substituted for the usual motor vehicle accidents. It included all accidental injuries incurred in the course of travel or transport of goods, mainly by bullock cart or bicycle. Motor vehicle accidents would have been included, but there were none.

Home accidents resulted in far more disabilities than any other of the four groups. As seen in Table 3, they accounted for 43% of the total. The striking difference in this experience compared with that in most western countries was in transport accidents; instead of occupying first place, they were last, in a proportion of 6%. Accidents in public places and at work stand in the usual relationship to each other and to home accidents, but make up a larger proportion of total mishaps.

TABLE 3.— ACCIDENTS IN 4 PUNJAB VILLAGES, MARCH 1, 1959 TO FEBRUARY 29, 1960, % DISTRIBUTION BY PLACE OF OCCURRENCE AND BY SEX OF PERSON INJURED

	NUMBER OF ACCIDENTS			% OF ALL ACCIDENTS		
Place	*Males*	*Females*	*Total*	*Males*	*Females*	*Total*
Home	50	168	218	22.1	60.0	43.1
Public Place	84	56	140	37.2	20.0	27.7
Work	70	49	119	31.0	17.5	23.5
Vehicular	22	7	29	9.7	2.5	5.7
Total	226	280	506	100.0	100.0	100.0

The kinds of accidents by castes conformed to the general distribution noted, except that accidents at work were unduly frequent among Chamars. Males predominated in all categories other than home accidents.

Most of the accidents listed, 90%, occurred within the village limits, which include the village itself and the surrounding fields belonging to its residents. This is explainable by the isolated nature of these little communities. The villages are usually one or two miles apart and with the connecting roads little more than tracks between fields, communication is limited. A trip to a nearby market town is an event that requires most of a day and sometimes two. Such visits are mainly for the sale of harvest produce. The villages are remarkably self contained; they raise most of their food, they weave the cloth for clothes, they can buy locally most of the daily needs they do not produce, and the economy precludes many luxuries. Two thirds of the accidents outside the village limits were vehicular and the proportion among men was even greater.

The two small villages of the study area, one with 298 and the other with 690 inhabitants, had the lowest accident rates, 53.7 and 66.7 per 1000 per year. Accidents in the larger villages of 1,433 and 1,956 population were at a frequency of 193.3 and 85.4 per 1000. Other than for numbers, the 4 villages were in good agreement as to kind and behavior of accidents in such qualities as the proportion of injured children and adults, and divisions of accidents by sex, season and place of occurrence. Sarinh village with the highest incidence had more than the usual proportion of persons with multiple accidents during the year. The two small communities had lower crude death rates over a 4-year period, including the year of the study, as indicative of generally better health conditions. Two of the health visitors engaged in the study had their residence in Sarinh; this closer association may have conduced to more nearly complete coverage in that village.

Seasonal Distribution of Accidents: The seasons of the year in north India do not fall readily into the usual four divisions. Summers are long and in two parts, an early hot, dry season and the later hot, wet period when the monsoons prevail. In Table 4, winter includes the calendar months of December, January and February, and spring is March and April. The hot, dry months are May and June, and the hot, wet period is July, August and September. Autumn includes October and November, although late November is fairly cold. Similarly, late April merges into the hot dry season.

The differences in accident frequency according to season were well defined. They appeared as much related to weather and climate as to other factors, notably farm activity. Spring and autumn are delightful times of the year in north India, and accidents were at a minimum, more so in spring than autumn. The hot wet months are decidedly difficult; the humidity is oppressive and the ever prevalent mud makes for a trying environment. Winters in the Punjab are not especially cold; temperatures rarely drop below freezing, but the homes and the clothing of the people are designed for a hot climate. Accident rates were high at those two seasons, Table 4, the summer prevalence being the greater and more prolonged with a peak in September.

Home accidents, the major component in

TABLE 4.— ACCIDENTS, ALL FORMS; INCIDENCE PER 1000 POPULATION PER YEAR AND % DISTRIBUTION IN 4 PUNJAB VILLAGES, MARCH 1, 1959 TO FEBRUARY 29, 1960, BY SEASONS

Season	*Number of accidents*	*Accidents per 1000 population per year*	*% of all accidents*
Winter (Dec. Jan. Feb.)	139	127.0	27.5
Spring (March, April)	47	64.4	9.3
Hot, Dry (May, June)	52	71.2	10.3
Hot, Wet (July, Aug. Sept.)	189	172.7	37.3
Autumn (Oct. Nov.)	79	108.3	15.6
Annual	506	115.6	100.0

this series, conformed to the general winter and wet summer prevalence, the two curves following each other closely. Accidents in public places were at a continued low level during the first six months of the year, reached their peak in September and experienced a brief secondary rise in late autumn seemingly related to the holidays and harvest festivals at that time. Work accidents showed interesting irregularities. In this highly agricultural community they would be expected to follow the curve of activity in the fields. This continues the year around although each season brings its special obligations. The hot wet season is devoted to ploughing and planting corn, peanuts and sugar cane. Action increases in September as the rains taper off and preparations begin for the main wheat crop. The harvests are in spring and autumn; these are especially active times. Winter brings attention to processing of sugar cane and winter ploughing, but compared with the rest of the year is relatively quiet. Work accidents followed the general pattern for all accidents, with a winter and summer prevalence and the major frequency in the hot wet months. During the two harvests, rates were low. Weather would appear to be a strong influence. Vehicular accidents were few; in so far as seasonal deviations could be recognized, the increases were in winter and the hot, wet season.

Accidents by Time of Day: The observed differences in frequency by season suggested the time element as a function of the day by day occurrence of accidents. Four periods of the day were distinguished: morning 8 to 12 o'clock, noon from 12 to 4 p.m., evening from 4 to 8 p.m., and night from 8 p.m. to 8 a.m. As expected, accidents occurred most often at the times of day when village activities were at their height. Almost half of all injuries were in the morning and a third in the evening hours. The main meal of the day is at noon and the extreme heat of early afternoon in summer precludes much else than rest. Work resumes at 4 p.m. and the evening meal comes with approaching darkness. There are no street lights in the villages and only oil lamps in the homes; night activities are thereby restricted. For these reasons, few accidents occurred during the noon and night intervals.

The distributions noted were constant for all ages, and likewise for both sexes. They held also for accidents according to place of occurrence except that transport accidents, always a minor consideration, were disproportionately frequent in the darker hours of late evening and night. Night accidents increased in summer and autumn, influenced by the common practice of families sleeping on the flat roofs of houses because of the heat, and men remaining in the fields during harvest time.

Multiple Accidents during a Year: Essentially one of every 10 persons in the study population had a disabling accident of varying duration sometime during the year. For 86% of 421 persons injured in a population of 4,377 this was limited to a single experience. About 11% had 2 accidents during the year and the remaining 3% had from 3 to 6. The frequency of multiple accidents was essentially the same for males and females and no demonstrable differences were observed according to caste. Children had repeated accidents somewhat more frequently than persons of other age groups but to no significant extent. The relatively high accident rates in this rural locality were attributable to the numbers of persons affected rather than to any fraction of the population being identified as accident prone.

Agents and Mechanisms: The commonest causative agents in this series of accidents, as presented in Table 5, were cutting and piercing instruments. This included knives, especially kitchen knives, hoes, axes, sickles, a sword and various other tools connected with work in agriculture, in trades and with household duties. The high accident rate for housewives coincided with the frequency of this general source of injury. Cutting and piercing objects, such as pieces of glass, sharply pointed sticks, tools and other objects without metal edges also were prominent. Together these two classes of agent accounted for 38% of all accidental injuries; they were the commonest cause at all ages. Domestic animals were among other important agents, with accidents variously attributed to cows, buffalo, camels, donkeys and dogs. They were more frequent among children than any other age group, with the elderly second. Fires and hot substances were especially prominent in the accidents of children and women. Accidents from contact with blunt objects such as the threshold of doors, logs and walls were accountable for 11% of total injuries. Falls were of a lesser order of frequency than in most other studies of the causes of accidents, because fewer elderly persons were at risk; at these ages and also among children they still had a prominent place. Machinery accidents were mainly among men and related for the most part to the hand-powered choppers used to prepare feed for animals.

Clinical Nature of Accidental Injuries: Lacerations were the commonest type of injury, representing almost half of the conditions listed in Table 6. Although far less frequent, fractures, dislocations and incised wounds were responsible for the greater part of accidents that ended in permanent impairment of function, Table 1. An outstanding medical impression from early contact with the villages was the number of crippled persons. That no more than 4% of accidents left residual defect would appear to be a low estimate.

Although adult females had a higher accident rate than males, the frequency of crippling accidents was no greater than for men. No differences could be determined within the three divisions by caste in seriousness of accidents. The leather workers had more accidents and, therefore, more crippling accidents but the relation between crippling and simple disabling injuries was the same. The injuries that occurred among men in September and May during the active seasons in agriculture resulted in more than the expected amount of crippling.

TABLE 5.— CAUSE OF ACCIDENTS IN 4 PUNJAB VILLAGES, MARCH 1, 1959 TO FEBRUARY 29, 1960, BY SEX

	NUMBER OF ACCIDENTS			% OF ALL ACCIDENTS		
Cause	*Males*	*Females*	*Total*	*Males*	*Females*	*Total*
Fall	20	26	46	8.8	9.3	9.1
Blow from falling object	7	8	15	3.1	2.9	3.0
Bites and stings of venomous animals	8	9	17	3.5	3.2	3.4
Other animals	25	24	49	11.1	8.6	9.6
Fire and explosion of combustible material	6	7	13	2.7	2.5	2.6
Hot substances and corrosive liquids	17	29	46	7.5	10.3	9.1
Cutting and piercing instruments	36	72	108	15.9	25.7	21.2
Cutting and piercing objects	35	51	86	15.5	18.2	17.0
Striking against or by blunt objects	28	30	58	12.4	10.7	11.5
Vehicular transport	28	7	35	12.4	2.5	6.9
Machinery	13	5	18	5.8	1.8	3.6
Unspecified	3	12	15	1.3	4.3	3.0
Total	226	280	506	100.0	100.0	100.0

TABLE 6.— TYPES OF WOUNDS IN ACCIDENTAL TRAUMATIC INJURY OF RESIDENTS OF 4 PUNJAB VILLAGES, MARCH 1, 1959 TO FEBRUARY 29, 1960, BY SEX

	NUMBER OF ACCIDENTS			% OF ALL ACCIDENTS		
Nature of injury	*Males*	*Females*	*Total*	*Males*	*Females*	*Total*
Lacerations	120	130	250	53.1	46.4	49.4
Incised wounds	27	56	83	11.9	20.0	16.4
Contusions	9	14	23	4.0	5.0	4.5
Puncture wounds	26	33	59	11.5	11.8	11.7
Fractures and dislocations	14	10	24	6.2	3.6	4.7
Burns and scalds	25	36	61	11.1	12.9	12.1
No visible injury	5	1	6	2.2	0.3	1.2
Total	226	280	506	100.0	100.0	100.0

A residual defect was noted most frequently in the accidents of children and of elderly persons and, as will be demonstrated later, they also had the higher death rates.

As judged by crippling effect, the seriousness of accidents in homes, at work, in public places and vehicular was essentially equal. There was a suggestion that accidents outside the village limits, predominantly vehicular, tended to end more frequently in loss of normal function, but the numbers were too small to judge. Other studies have suggested that injuries experienced under unfamiliar conditions tend to be more serious.

Disability in Non-fatal Accidents: The days of disability experienced by the 484 injured persons who eventually recovered full function are presented in Table 7. That the accidents included in this series were truly disabling is evidenced by the small proportion of persons with disability lasting a single day. The mode was 2 days and for all patients the average was 5.9 days.

Males with accidental injury were disabled somewhat longer (7.0 days) than were females (5.0 days) with no distinction by social status as determined by caste. It is believed from other evidence that this reflects generally more severe accidents, although the answer may be that men were able or chose to take their troubles more seriously. An analysis by sex and age showed a regular progression of average days of disability for males from 6.2 days for children of 0 to 14 years to 13.2 days for persons 65 years old or more. For females, the average period of disability was not only shorter but almost the same at all ages except for children who slightly exceeded (5.9 days) the average disability for females of 5.0 days. Agricultural workers had relatively prolonged disability, as did other manual laborers such as carpenters and masons; that for tradesmen was short.

Accidents by falls resulted in longer disability than most others, presumably because they were commonest in elderly persons. Injuries by animals and by fire were accompanied by periods of disability

TABLE 7.— PERSONS TEMPORARILY DISABLED BY ACCIDENTAL INJURY IN 4 PUNJAB VILLAGES, MARCH 1,1959 TO FEBRUARY 29, 1960: DURATION OF DISABILITY IN DAYS

	MALE		FEMALE		TOTAL	
Days disability	*No. of accidents*	*% all disabling accidents*	*No. of accidents*	*% all disabling accidents*	*No. of accidents*	*% all disabling accidents*
1	14	6.5	29	10.8	43	8.9
2	53	24.5	83	31.0	136	28.1
3	21	9.7	38	14.2	59	12.2
4–7	69	31.9	74	27.7	143	29.6
8–14	31	14.4	26	9.7	57	11.8
15–21	18	8.3	10	3.7	28	5.8
22–29	2	0.9	4	1.5	6	1.2
30–39	4	1.9	2	0.7	6	1.2
40 +	4	1.9	2	0.7	6	1.2
Total	216	100.0	268	100.0	484	100.0

prolonged beyond the average. Although more accidents in this series resulted from cutting and piercing instruments than any other cause, the disability that followed was short, 4.3 days.

FATAL ACCIDENTS

The larger investigation of population dynamics, of which the accident study was a part, provides information on fatal accidents. All deaths during 3 years were investigated by individual case study in a rural population of 12,022 people. The 23 deaths from accidents give an annual mortality of 63.3 per 100,000 population. The numbers are small but they have the merit of exactness.

Accidents ranked ninth among leading causes of death in the population studied. The first three conditions, acute diarrheal disease, pneumonia and tuberculosis, were firmly established as the more significant factors in a total mortality of 17.0 per thousand per year. The next six causes, including tetanus, birth injuries, cancer, heart disease, typhoid fever and accidents were so closely grouped that chance occurrence could give an order with accidents ranking as high as fourth.

The disease-specific death rate for accidents, 63.3 per 100,000 population per year, clearly indicates the importance of this health risk. Few countries cited in the Demographic Yearbook have higher rates and most of them are in similar preindustrial parts of the world. Rates in the United States for a corresponding year were 51.7; and this rural population had no deaths from traffic accidents, there were no factories and no electric current in the 11 villages. Accidents have an evident current seriousness which may be expected to increase with an improving economy and additions to existing risks from sources such as those just stated.

As in most recorded experience, accidental deaths were more frequent among males than females, the respective rates being 76 and 48 per 100,000. This relationship existed despite females having more accidents than males; they were of apparent lesser consequence. Thirteen of the 23 deaths were among children 0 to 14 years of age, to give an age-specific death rate for accidents of 88 per 100,000 per year. The highest rate was for persons aged 65 years or more, 294 per 100,000. Young adults of 15 to 24 years had a death rate of 63 and for the productive years of 25 to 44 there were no deaths, although accidental injury was of appreciable frequency, especially among women. Deaths from accidental injury centered among children and the aged, as in most countries where good data are available.

Home accidents accounted for 9 deaths, those in public places for 9 and 5 were in the course of work. Other than for deaths in public places, where most were among men, the distribution between sexes was even. There were no deaths from transportation accidents, motor or otherwise.

Burns or scalds were responsible for 5 deaths. In the absence of a shopkeeper who made and sold fireworks for a holiday celebration, a group of children who had viewed the process decided to try making their own. The resulting explosion wrecked the shop and killed 3 of them. Another unfortunate little fellow, 2 years old, fell into a cauldron of boiling sugar cane juice.

An added 5 deaths were from injuries by animals. Three were by water buffalo; one girl was dragged a mile or more across a field. A boy aged 14 years sat in the Indian sunshine chewing sugar cane and leaning against a tethered camel; without warning the animal rolled over on him. An elderly man was kicked to death by a horse.

The drownings were variously in a village pond, in a canal and through fall into an open well. Three deaths were from infections after injury and 2 from poisonings. Falls caused the deaths of 2 elderly men, less than usual as judged by other studies. Suffocation after aspiration of a foreign body, a bolus of sugar cane, was responsible for one death and lack of care of infants another two.

Discussion and Summary

The death rates for traumatic injury in the tropics are a good indication that accidents are as much of a health problem there as in countries of the temperate zones, where they are regularly among the leading causes of death. Deaths are not the most satisfactory measure of the health significance of accidents because much of the effect is in the subsequent days of disability and the resultant crippling. Workable estimates of the nature and frequency of non-fatal accidents are to be had in some countries from the results of field surveys of sampled populations. That sort of investigation has not been made in tropical regions.

The physical, social and biologic environment differs so greatly from the western world, where most surveys have been made, that the results there have limited usefulness in interpretation of tropical situations, especially for rural populations which are numerically the important element. The mechanization of agriculture, the variety of chemicals used, and the common use of motor transport give occupational risks in Europe and America of an independent order. The comparisons with conditions in the United States, to be made momentarily, are not from choice, but because data from American sources are what is available. An understanding of the accident problem in rural tropical regions depends on information to be gained through epidemiological field studies, of cases as well as deaths, and made in representative areas. This investigation in the Punjab is a beginning.

The average annual death rate from accidents in 11 Punjab villages was 63 per 100,000, as determined by case study of all deaths among 12,000 people over a 3-year period. The rate was high as judged by death rates reported from other parts of the world. How it compares with experience in urban communities of the same region is unknown. In the United States, rural populations have higher accident rates than urban and both rank relatively high among countries of the world. Preliminary estimates of death rates from accidents among rural residents in the United States for 1960 were 55 per 100,000 people, that for the general population 51.7.

An appreciable part of accidental deaths in rural America was attributable to motor vehicle accidents, 24.8 per 100,000. In the Punjab studies there were no deaths from transport causes. The death rates for all accidents other than motor vehicle were thus 30.2 in rural United States and 63.3 in this part of north India. Life in the Punjab villages is hard; it also has its element of danger if one is to judge by the frequency of accidents in home and public places. The accidents that occur are of another kind than by motor vehicle, travel and the complicated life in great cities, but the risk is real. Furthermore, the mechanization and other changes which have made agriculture. an industry in America and presumably added to its hazards seemingly do not compensate for the risks inherent in cultivation of land by manual labor and an animal force.

For every death by accident in this series there were 7.9 non-fatal accidents that ended in crippling of varying degree. Comparable figures for farm practice in the United States are not available, but the ratio for accidents in the general population has been estimated on the basis of survey data at 3.9 crippling accidents per fatal accident. Although women in this experience had more accidents than men, the greater frequency of crippling was among males.

Total disabling accidents in the Punjab were in a proportion of 183 to each fatal accident. The corresponding value for the general population of the United States was 102. The large number of motor vehicle accidents accounts for a part of the higher case fatality in the United States; the number of deaths per unit of accidents is especially great in that class of injury. Home accidents were the commonest accidental injury in the Punjab and in this and other populations the fatality is regularly low. Although accidental injury in the study population was close to twice that of American experience, the proportion of accidents ending in crippling was not far different, 3.8% in the United States and 4.3% in the Punjab.

The situation presents certain anomalies. The Punjab series has a slightly higher mortality and an appreciably lower fatality than in the United States. A reasonable explanation is greater numbers of accidents of an average lesser severity. However, the proportion of crippling accidents to deaths was essentially twice that in the United States, with the suggestion that accidents in the Punjab were of greater severity. On the other hand, the relation of numbers of crippling accidents to total accidents was about the same in the two localities, to imply that accidents were of equal severity; twice as many crippling accidents occurred in the Punjab because there were twice as many accidents. Two explanations are offered for the commoner occurrence of crippling, with both likely involved. Deficiencies in medical care of injuries is one possibility; the other is a kind of accidents with the usual capacity for crippling but less often ending in death.

Since only 6% of accidental injuries were related to transportation, motor or otherwise, the other 3 commonly recognized classes were proportionately more prominent than in most surveyed populations, along with greater rates of incidence. Home accidents accounted for 43% of the total, accidents in public places for 28% and the accidents associated with work 24%. Their order of frequency was the same as in most places where accidental traumatic injury has been studied. Aside from the conspicuous exception provided by motor vehicle accidents, this experience had another unusual characteristic in that incidence rates were greater for females than males, at all ages past childhood, largely because of the frequency of home accidents.

The health problems of the tropics are predominantly with infectious diseases, nutrition and environmental sanitation. As both older and newer governments enlarge their health facilities, practical considerations and a sense of proportion require that these interests continue to have major attention. The consistent progress in the control of infections makes equally certain that other features of a modern public health, such as mental disorders, accidents and the chronic degenerative and neoplastic diseases, will find opportunity for development. Accidents have a solid claim to priority. They are presently an important cause of death that presumably will increase with industrialization and an ageing population. The observations here reported indicate a special significance in the health of mothers and children.

This work demonstrates the pertinence and feasibility of sophisticated accident research under primitive conditions. The investigation made possible the identification of (1) the frequency of such accidents in the area studied; (2) the variety of accident phenomena represented and their relative importance; and (3) the age- and sex-specific rates. Also of importance are the findings with respect to shifts in the ratio of crippling to merely disabling injuries in comparison with the ratios observed in Western countries. To the extent to which similar observations can be made in other preindustrial societies, this may serve, as the authors indicate, as a device for measuring one aspect of the impact of inadequate medical care, a point of considerable interest from the standpoint of the factors that influence the results of accidents.[6]

Of additional interest are the rates for women between the ages of 5 and 64 years. If the investigators had not analyzed the data in terms of age, the results, though still showing higher rates for females than males, would have been of much less use, since the age groups contributing the preponderance would not have been identified.

As the authors also mention, vehicular accidents of all types are, as might be expected, of relatively minor importance in the area studied. Despite this, the overall accident rates are equal to or higher than those occurring in most industrial countries. The very substantial variation in the rates (per year) with season of year is also of considerable interest, not only in terms of weather per se but also with respect to the social and occupational activities of the population at risk, which, as the authors note, change with season.

Despite Gordon's emphasis (in the earlier paper in this chapter) on analyses in terms of host, agent, and environment, this form of analysis is not so explicitly spelled out in the present selection as might have been expected. It is noteworthy also, particularly in connection with Table 5, that the "causes" listed are in fact chiefly the mechanisms by which the injurious energy exchanges were produced and that relatively little attention is paid to the factors whose interactions led up to the accidents described. This is in no way a criticism of this investigation, since its descriptive objective was very successfully realized. It would, however, be of considerable interest to follow up this work with an analytical study directed at the elucidation of the more intimate factors involved in the initiation of these remarkably frequent accidents.†

The process illustrated by this paper, of beginning with the general and then focusing on the increasingly specific in order to move closer to an understanding of the factors that initiate accidents, makes necessary the study of increasingly more subtle and specific characteristics of accident circumstances and of those involved. Thus, for example, one moves from descriptions of the accident-involved only in terms of age and sex to descriptions of additional characteristics that may or may not be associated with age and sex.

HEALTH AND SAFETY IN TRANSPORTATION

—*Ross A. McFarland, Ph.D.*

Although examples might be selected from other accident areas, this contribution by McFarland serves as an excellent illustration of the process of increasing discrimination. It serves also as an introduction to the next chapter, which is concerned with some of the details of data collection that must be considered by the investigator concerned with variables more subtle and discriminating than those discussed up to this point.‡

† The reader is also referred to a methodological study based on the same work.[17] In it the same investigators discuss the reliability of recall concerning the accidents studied and demonstrate that the *reported* totals of the more minor accidents decreased the less frequently the villagers were interviewed. This is a common source of bias in studies in which interviewing is used as the source of information about previous accidents. See Chapter 3.

‡ This paper is in part a synopsis of the extensive contributions of McFarland and his colleagues. Their publications are numerous, and several of them are referenced in this selection: of particular note is *Human Variables in Motor Vehicle Accidents, a Review of the Literature*.[18]

THE ASSURANCE of health and safety in transportation has become one of the basic needs in modern life. In certain areas of the world, safety in transit is assuming even greater importance than problems relating to food, shelter, and clothing. In the United States, for example, extensive mechanization of the environment, diverse industrial procedures, and increasing use of transport vehicles have resulted in new threats to the well-being of large sections of the population.

The important role played by human variables in causing accidents brings the control of accidents within the province of preventive medicine and public health. The physician and the public health officer, with broad training in the biological sciences, are especially qualified to improve safety in industry, in the home, and in various forms of transportation.

Efforts in the control of accidents can be strengthened by the application of epidemiological techniques. The methods which have been used so effectively in the control of infectious disease can be broadened to prevent injuries, especially on the highway and in the air. Since most accidents have multiple causes, the interactions between the "host" (driver, pilot, or operator), the "agent" (vehicle, plane, and equipment), and the "environment" are important considerations in attempts at control. While the host factors are of particular interest to physicians, they must be viewed in their relationships to the agent and the environment for an adequate understanding of accident causation.

Because human variables are especially important in causing accidents, the physician or the public health officer has a direct responsibility in the prevention of injury, Moreover, since memory operates most effectively when reinforced by emotion, the physician is in an especially favorable position to teach while treating and to indoctrinate patients with the principles of accident prevention. It is thus of great importance for the physician to take the initiative in identifying the causes of accidents in order to institute preventive procedures.

Current approaches to the control of accidents may possibly be reaching the limits of their effectiveness. The next significant advances in safety may result from a combined approach which includes the engineering and biological sciences. This collaboration is not new in medicine, and such an approach has been the basis of many important developments. For example, the control of malaria was achieved by cooperation between the entomologist, the sanitary engineer, and other specialists. The physiologist, the psychologist, the anthropologist, the engineer, and the physician can similarly cooperate to obtain basic data in order to achieve improved prevention of motor vehicle accidents.

TRANSPORTATION FACTS AND FIGURES

A few examples of the extent to which passenger transportation has increased in modern times show the magnitude of the problem.

In 1956, buses, automobiles, taxis, and trucks, operated by 77 million licensed drivers, traveled some 630 billion miles on the highways in the United States. Drivers and passengers in automobiles and taxis alone accounted for 970 billion passenger-miles of travel; 51½ billion passenger-miles were recorded in intercity bus operations.

In aviation the volume and speed of travel have been increasing very rapidly. During the first 24 years of the air transportation industry, that is, up to 1950, 100 million revenue passengers were carried by scheduled domestic and international carriers in the United States. By 1957, 349 million revenue passengers had been carried. The number of revenue passengers on airlines of the United States in 1956 was about 46 million. These represented about 70 percent of the total world volume of 68 million revenue passengers on airlines.

Reprinted, with permission, from *Public Health Reports*, *73*:8:663-680, August 1958. Portions of the text and one table have been omitted.

In 1956 for the first time more passengers were carried to Europe by air than by ocean liner, and 68 percent of all passenger traffic between the United States and other nations was by air. Helicopter scheduled airlines were nonexistent 5 years ago. In 1957, this new type of service carried 152,000 passengers.

The transition from piston engines to jet propulsion will impose new and interesting problems in the next few years. Approximately 350 jet transports are now on order. These planes will carry as many as 140 passengers each at a cruising speed of approximately 600 miles per hour.

The number of revenue passengers using the railways exceeds 400 million per year, excluding commuters. Also, in 1956, more than 9 billion separate fares were paid by local transit riders.

It is now apparent that almost everyone uses some mode of travel or another, not once, but many times during the course of the year. The exposure of our populations to travel hazards has reached enormous proportions both in relation to accidental injury and the threat of exposure to certain diseases.

The frequency of accidents now presents a major problem. Each year approximately 95,000 persons are killed in various kinds of accidents in the United States (fig. 1). About 350,000 others receive permanently disabling injuries, and temporary disabilities severe enough to keep them away from work for at least a day are incurred by 93 million persons. These accidents occur mainly in the home, on the job, and during transit. Accidents in various forms of transportation, particularly on the highway, have reached epidemic proportions. Since the invention of the automobile there have been more than a million fatalities in motor vehicle accidents in the United States; in 1957, highway accidents accounted for 41 percent of all accidental deaths. The annual direct costs of traffic accidents approximate 2 percent of the national income.

Fatal accidents involving persons under 35 years of age formed a large proportion

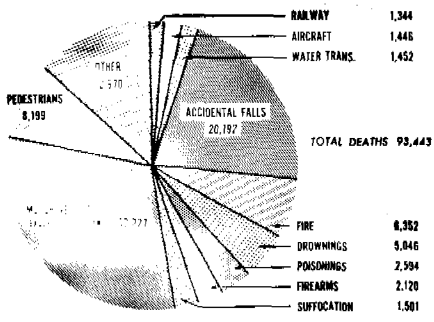


FIG. 1. Accidental deaths in the United *States during 1955.*

of the total deaths in highway accidents. This implies an enormous drain on the productive resources of the country. Accidents are the leading cause of death for persons between 1 and 34. They are exceeded only by heart disease and cancer for those between 35 and 44 years of age.

In the armed services, accidental trauma is now a major problem. During World War II the United States Army reported more deaths among its soldiers caused by accidents than by disease for the first time in its history. In the Korean conflict more than half of the hospitalized casualties resulted from accidents rather than from enemy action. Of these, 70 percent were incurred in motor vehicle accidents. The frequency of motor vehicle accidents in all three branches of the Armed Forces has become very serious, and accidents now exceed upper respiratory infections and rank first as the leading cause of man-days lost. Motor vehicle accidents account for about 2,100 fatalities of servicemen each year, a large majority occurring while personnel are off duty.

The integration of motor vehicles into our way of life has become very costly in fatalities, injuries, and damaged equipment. In spite of the enormous increase in volume of highway traffic, there has been a significant decrease in accident rates during the past 25 years. For example, in 1957 the fatality rate per 100 million miles of travel was only 5.9, in comparison with the rate of approximately 15 about 20 years ago. Nevertheless, the actual number of persons killed or disabled and resulting costs to the nation's economy have increased from year to year with only a few exceptions apart from the period of restricted travel during World War II. In 1957 there were approximately 38,500 deaths and 1,350,000 injuries disabling beyond the day of the accident. According to present trends, it is estimated that 1 of every 10 persons in the country will be injured or killed in a traffic accident during the next 15 years.

The safety record of scheduled airlines in the United States is an enviable one in relation to the exposure. Only 154 fatalities were reported for 1956, with the 128 deaths in the Grand Canyon accident accounting for approximately five-sixths of this total. In 1957, there were 31 deaths. Business flying is reasonably safe, but private flying has a relatively poor record. There were 655 fatalities in 1956 in 3,411 accidents among 65,000 business and private planes. Thus, 1 in about every 19 of these airplanes was involved in an accident. Crop dusting by airplanes, of great importance to both public health and agriculture, is also hazardous. Military flying obviously involves increased hazards. However, in United States naval aviation there is now only about one fatality per day. For example, in 1956, there were 413 deaths attributable to aviation accidents. In the U. S. Air Force, with its far more extensive operations, deaths have been reduced to about three per flying day. In 1955, there were 825 fatalities.

To determine precisely the relative safety of different kinds of transportation is impossible because of the lack of a satisfactory common denominator for a valid comparison. The nature and frequency of the hazards encountered differ greatly among the various forms of transport, as does the number of passengers exposed to danger of injury in the different types of vehicles.

At present, death and injury rates per

TABLE 1.— ACCIDENTAL DEATHS OF PASSENGERS PER 100 MILLION PASSENGER-MILES IN UNITED STATES TRANSPORTATION, 1947-56

Type of carrier	*1947–51 average*	*1952*	*1953–55 average*	*1956*
Scheduled air transport:				
Domestic	1.6	0.37	0.49	0.64
International	1.1	2.98	.03	.17
Railroad passenger trains	.27	.04	.10	.20
Intercity buses	.19	.16	.14	.16
Automobiles and taxis	2.2	2.8	2.7	2.7

100 million passenger-miles are used in estimating the safety of travel, and, on this basis, table 1 shows the accident death rates in passenger transportation. While deaths per 100 million passenger-miles is not a wholly satisfactory basis for this comparison, it appears that on the whole buses and trains have the lowest rates. Those for automobiles and taxis are much higher, and air transportation occupies a middle position, slightly above those for trains and buses. Actually, the accident frequency rates for air transportation are quite low; the fatality rates reflect chiefly the fact that there are few survivors in the major accidents.

EPIDEMIOLOGICAL APPROACH

A basic step in the application of the epidemiological approach is determining the fundamental physical, physiological, and psychological characteristics of the host. When these data are correlated with the characteristics of the agent (vehicles and equipment) under specific environmental conditions, the resulting information will shed light on the causes of accidents and aid in developing preventive measures. To obtain this kind of information experimental and clinical studies, epidemiological surveys, and careful statistical analysis are required.

An epidemiological approach to highway safety in the armed services was applied in a recent study sponsored by the Commission on Accidental Trauma of the Armed Forces Epidemiological Board. About 88 percent of highway accidents in the Navy and Marine

Corps occur while the personnel are off duty. The epidemiological method was used to study this problem at a major Marine Corps base.

It was previously supposed that the main problem concerned fatal accidents during weekend periods on considerably long automobile trips. The study showed, however, that 96 percent of the accidents occurred within a 50-mile radius of the base, and 71 percent within 10 miles. The greatest percentage of accidents occurred between 6 p.m. and midnight, that is, during the evening recreation period. The analysis identified the young, unmarried enlisted men of low rank who live on the base in government quarters as having a highly disproportionate share of the accidents. These findings have formed the basis for a new accident control program at this military installation.

It will not be possible to present a complete analysis of the epidemiological approach in both the highway and air transport fields, and primary emphasis will be given to the findings relating to highway safety. However, there are several interesting problems in the field of air transportation which have far-reaching implications for the health and safety of large sections of the population, and a few of these will be singled out for special mention. The first one concerns the medical care of the flight crews and the handling of problem medical cases. This will be considered in the discussion of host factors. The second refers to the possibility of spreading disease by aircraft, which will be treated under the heading of host-agent factors in health and safety. The third involves host-environment relationships in connection with the transportation of patients by air, and the problems which may arise from a loss of pressure in pressurized air transports.*

Host Factors in Accidents

Thus far no single characteristic of drivers has been identified which accounts for a large proportion of accidents on the highway. This is true for a variety of sensory, psychomotor, and psychological investigations. A few useful generalizations may be made, however, about driver characteristics in relation to accidents.

Results of a number of studies clearly indicate that, in relation to their numbers, drivers up to the age of about 25 have accidents more frequently than do those from 30 through 60 or 65 years of age. The most recent and complete information, from Massachusetts and Connecticut, indicates the highest rates for the youngest drivers, those of age 16. The rate decreases with succeeding years of age, rapidly at first and then more slowly (fig. 2). It levels off at about age 30 and remains stable and relatively low through age 65. Data related to ages above 65 are as yet too meager for interpretation. The factors responsible for the higher rates for youthful drivers are believed related to inexperience and to psychological characteristics of youth in the adolescent and early adult phases of adjustment.

In the United States, roughly 10,000, or about half, of the high schools in the country offer classroom instruction in highway safety and training in the operation of automobiles. A number of studies have been made on the effectiveness of this training. The results, shown in figure 3, agree substantially that the accident rates of trained drivers are about half as high as those of untrained, at least during the first few years of driving. Many of the reports also indicate fewer violations of traffic regulations by trained drivers. It is also apparent that classroom instruction alone is less effective than a combination of classroom instruction and behind-the-wheel training. It thus appears that the adequate initial training of drivers constitutes an important method of reducing accidents in a portion of the driving population presently characterized by the highest rates. There is still the need, however, for research on

* Since these are omitted below, the interested reader should refer to the original. Eds.

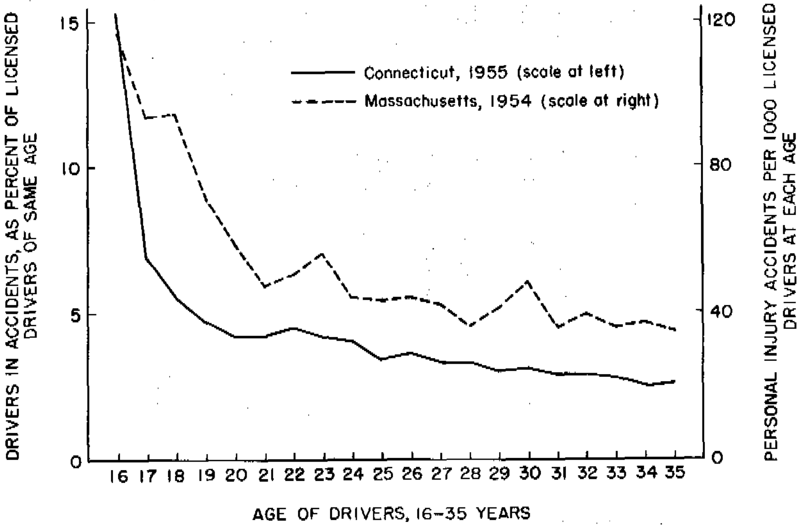


FIG. 2. Frequency of accidents among drivers aged 16 to 35, based on Connecticut and Massachusetts experiences.

what should be taught, on ways to provide training in driving under adverse conditions and in the handling of emergency situations, and on ways to expand training programs to include all beginning drivers.

Of the greatest importance in driving safety are the attitudes and personal adjustments of drivers. A useful concept which has been developed in this area is that "a man drives as he lives." Studies of accident repeaters and accident-free drivers carried out in Canada showed that maladjustments in meeting the personal and social demands of living were far more frequent among the accident repeaters than among accident-free groups. A promising method for the identification of accident-repeater drivers resulted from this study. It was found that, as a group, the accident repeaters could be differentiated from the accident-free drivers on the basis of the number of contacts with such agencies as the civil and criminal courts, collection agencies, public health clinics, and social welfare agencies (fig. 4).

The same procedure was subsequently applied to a large sample of truck drivers in a study at Harvard. Accident-repeater and accident-free drivers were carefully matched to meet rigid standards, and various public records were searched for their names. Findings very similar to those in the Canadian study were obtained. A statistical analysis by the chi-square technique was made to determine the relative usefulness of the various indexes of antisocial or maladjustment tendencies in differentiating those with repeated accidents from those without accidents. The relative value of selected items in discriminating between accident-free and accident-repeater drivers has been developed in the following manner:

ITEM	CHI-SQUARE
Court record of automobile offenses	7.48
Minor violation in motor vehicle records	6.76
Court record of offenses against persons	6.43
Unfavorable business inspection report	3.84
Court record of offenses against self	2.55
Court record of offenses against property	2.01

The values for the individual items having greatest significance were applied as weights to the information obtained on a new sample of unselected drivers. In this preliminary experiment the procedure identified the accident repeaters in the sample with an accuracy of 85 percent.

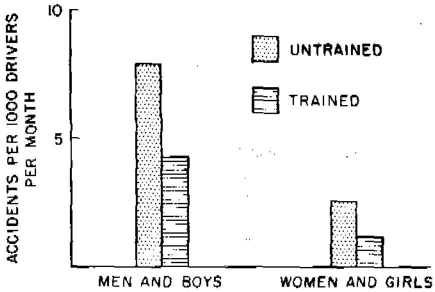


FIG. 3. The safety record of trained drivers compared with that of untrained, based on 1,226 accidents during an exposure of 300,536 driver-months.

In another study information from the service records of 210 military pilots who had been killed in noncombat aircraft accidents was compared with records of a 20 percent sample of reserve pilots discharged after satisfactory service (personal communication). A record of disciplinary charges was found for 48 percent of the fatal accident group as against 31 percent of the control group. "Violation of flying orders" was the most discriminative type of offense—21 percent of the fatal accident group as against only 2 percent of the controls. Nonflying disciplinary infractions were also significantly different in the two groups, the accident group rating higher in resistance to order and discipline. Also noted in the accident group were the larger proportion of pilots who had not completed high school and the larger proportion of pilots who changed jobs frequently prior to enlistment.

An intensive investigation of personality factors in relation to accidents is currently being made at the University of Colorado. This approach includes extensive psychological testing and intensive psychiatric evaluation. One group test--a modified form of the Allport-Vernon Scale of Values—has provided a 70 percent accurate discrimination between no-accident drivers and those with a high-accident record. Characteristically, and in contrast with the accident-free, those drivers who have had accidents scored high on the theoretical and aesthetic scales and low on religious values. Through a combination of the test results and the clinical material, it appears that the accident-prone driver is less likely to identify himself with the father, more likely to consider authority figures unpleasant, and more likely to show an excess of regressive, masochistic fantasy. The most useful tests are now being given to all of the high school students in the city of Denver. The results will be correlated with their subsequent driving records.

In situations involving time stress and complex reactions, the lower accident rate for adult and middle-aged drivers is clear, but for persons past middle age there is some evidence that the rate may increase. It is known that reaction times tend to become longer with advancing age, and impairment in the efficiency of all the senses occurs. Many persons, however, develop compensating habits offsetting these losses. It is believed, for example, that older drivers tend to drive slower and to do less driving at night.

Research carried out at Cambridge

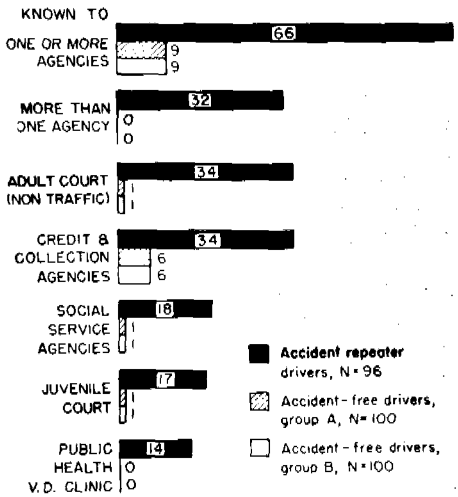


FIG. 4. Personal and social adjustments of accident repeaters and accident-free drivers matched for geographic location and driving experience.

University on the effects of aging on skilled performances has suggested the kinds of situations in which aging persons might be especially vulnerable to accidents. The implication is that when an older driver is required to assimilate a novel or complex situation instantaneously, and to carry out a rapid sequence of reactions, he is apt to become confused and make errors. Without time pressure and in familiar situations, a more adequate or efficient response can be expected.

Many accidents occur when the efficiency of the driver is impaired by some temporary condition. The efficiency and safety of driving may be adversely influenced by a variety of temporary states, although, in general, statistical proof of the importance of a given type of condition may be very difficult to obtain. For example, the role of fatigue in asleep-at-the-wheel accidents appears quite clear, but fatigue may be a more subtle factor in many other accidents. When drivers are emotionally upset or preoccupied with personal problems, alertness to the driving situation may be diminished. Alcohol is widely cited as a cause of accidents. And what may be the influence of concurrent disease or of various abnormal physical conditions? Also, is safety compromised as a result of either the direct or side effects of various drugs and remedies taken for a variety of medicinal purposes? The following are several of the findings concerning the influence of temporary conditions.

Driver fatigue is not only related to the length of time spent in driving. Consideration also must be given to such factors as amount and quality of previous rest, the nature of activities prior to driving, and concurrent emotional stress. In addition to the subtle disorganization of skill which develops with increasing fatigue, drivers when extremely tired may experience hallucinations of obstacles on the highway, and a number of accidents have been traced to actions taken by drivers to avoid collision with these imagined barriers. When interviewed confidentially, more than half of a sample of professional drivers engaged in long-trip driving admitted having had such experiences.

Driving skill is adversely influenced in many with as little alcohol in the blood as 0.03 and 0.04 percent. The likelihood of an accident increases constantly as the alcohol in the blood increases from the lowest levels. The risk at 0.10 percent is estimated to be more than twice that at 0.05 percent, while the risk at 0.15 percent appears about tenfold (table 2). These data are from a recent study in Canada. Additional data from the same study show that as the level of blood alcohol increases, there is an increase in driving errors which result in accidents. In several series of autopsies recently made on drivers killed in accidents in the United States, significant amounts of alcohol were found in the blood and brain fluids of more than half of the cases.

A physiological fact which may have special importance is that, while initially there is a close correspondence between the levels of blood alcohol and brain alcohol, the alcohol is eliminated more slowly from the fluids surrounding the brain than from the blood. Thus, elevated concentrations of alcohol may be found in the spinal fluid for some time after blood values have become negligible.

Through control of problem medical cases preventive medicine has an important role in reducing accidents on the highway and in the air. The questions of physical fitness to drive and the influence of pathological processes in accidents are of particular interest to physicians.

TABLE 2.— ACCIDENT HAZARD IN RELATION TO BLOOD ALCOHOL

Percent of alcohol in blood	*Percent of accident drivers (N—432)*	*Percent of drivers not in accidents* (N—2,015)*	*Ratio of accident drivers to non-accident drivers*	*Relative accident hazard*
0.0–0.05	77.5	91.3	0.85	1.0
0.05–0.10	7.1	5.4	1.31	1.5
0.10–0.15	4.0	1.9	2.1	2.5
0.15 and over	11.3	1.4	8.1	9.7

* Drivers not involved, but passing the accident scene shortly after the accident.

Most authorities would agree that epileptics, diabetics requiring insulin, and those with certain heart conditions should not operate public highway conveyances or pilot airliners because of the hazard of a sudden loss of consciousness. But what of the influence of such conditions in the general driving public and what cutoff points should be kept in mind? There are, for example, about 6 million truck drivers in the United States, yet it is known that only a small proportion of them receive thorough physical examinations, and that the development of adequate medical programs for the large number of workers in the transport industry remains to be accomplished. It would be expected that in this occupational group, a certain number use insulin, experience temporary impairments of consciousness, or have fairly advanced heart disease of one form or another.

In the interest of prevention, does not the physician have a responsibility to indoctrinate the patient and the public regarding the influence of disease on driving and the effects on human behavior and efficiency of prescriptions and medications employed? Within the patient-physician relationship, must not the cardiologist, for example, estimate the likelihood of sudden loss of consciousness in various forms of heart disease and advise his patients whether it is safe to drive? In this connection, what advice should the physician give his diabetic patient? Or how is safety compromised when with advancing age changes in sensory functions and reaction time can no longer be compensated by training and experience? How can the patient-physician relationship be reconciled with the physician's responsibility for the prevention of injury when there is a question of public safety?

Unfortunately, there are few controlled experimental data available to determine precisely the role of various clinical conditions in highway safety, or to establish medical criteria and cutoff points concerning fitness to drive. Conditions involving a sudden loss of consciousness provide the most dramatic illustrations of the influence of disease in accidents. For example, in England the incidence of coronary thrombosis over a 5-year period was studied among the bus drivers of the London Transport Executive. There were 133 cases. Six prompt fatalities occurred while the driver was at the controls of a bus. Three of these resulted in accidents. In the other three attacks, the operator was able to stop the vehicle without harm.

The need for research to evaluate the influence of specific conditions in traffic accidents and to establish critical cutoff points is very great, and physicians obviously can make important contributions in this regard. The limitation on driving for persons with various illnesses or disabilities presents a serious problem. The American public, moreover, does not readily accept limitations on personal freedom. An arbitrary prohibition of driving for all those afflicted with certain conditions would be needlessly restrictive and unfair to many persons, and cooperation between the medical profession and the motor vehicle authorities in handling these problems on an individual basis is essential. Several studies have shown that drivers with quite severe physical limitations may have safe records if they are carefully supervised by their physicians. In Massachusetts, for example, a satisfactory safety record has been found with certain high-risk drivers permitted to hold licenses and drive under a program of continuing medical surveillance. These drivers include persons with such disabilities as epilepsy, diabetes, multiple sclerosis, and various amputations and paralyses.

If the problem of medical fitness to drive is to be satisfactorily worked out, large-scale studies of persons with various disabilities must be carried out to let them help decide which of this group should not drive. For example, a physiological and clinical study of 1,000 diabetics, together with statements from them about critical incidents and episodes and how they have been influenced in a dangerous way, would supply needed information in this area. Such a study might prove a more acceptable approach than the setting of arbitrary cutoff points without an experimental basis. A study of this type is at present being carried out at the Harvard School of Public Health.

In the field of air transportation, airline pilots receive periodic physical examinations through designated medical examiners of the Civil Aeronautics Administration. A few of the 80 airlines of the world have good medical departments, but less than one-fifth of the scheduled airlines have formal medical organizations. The report that each month, for a 5-month period in 1957, a pilot on active duty died while in the cockpit will emphasize the importance of continuing medical supervision, as well as of the value of having a co-pilot. One of the pressing problems in this area relates to the changing age distribution of airline pilots. With many of these men now entering age groups beyond 45 and 50, many problems of health and safety may be anticipated.

The findings for 232 problem medical cases among transport pilots have been followed through a period of 20 years. Permanent grounding resulted in only 83 cases, all of the others having returned to duty. The majority of cases were classified as neuropsychiatric and cardiovascular. Such studies are of great value in the delineation of cutoff points for airline pilots, and, furthermore, they do not support the belief held by many pilots that a serious illness necessarily results in permanent grounding.

Host-Agent Relationships

A number of findings concerning transport health and safety relate to interactions between the host and agent. In the vehicular field host-agent relationships are primarily concerned with the effective integration of the man-machine combination. In order to promote that integration, automotive equipment should be designed with regard to human capacities and limitations.

Mechanical design should be intimately related to the biological and psychological characteristics of the driver. It is reasonable to expect, therefore, that machines should be designed from the man outward, with instruments and controls considered as extensions of his nervous system and appendages. This implies that the automobile should be built around the operator, with due regard for his requirements and capacities. When this is done there should be fewer accidents and no extensive redesigning of equipment after it is put into use, but until this is done, it is hardly fair to attribute so many accidents to human failures.

In general, any control lever that is unnecessarily difficult to reach and operate, any instrument that is difficult to read, any seat that induces poor posture or discomfort, or any unnecessary obstruction to vision may contribute directly to an accident. In addition, the cumulative effects of such difficulties lead to fatigue, to the deterioration of driver efficiency, and perhaps, eventually, to an accident.

Numerous examples of faulty design in modern vehicles may be found from the standpoint of the range in body size of the drivers, the biomechanics of human movements and postures, and the characteristics and limits of human perception. A few examples are taken from a study at Harvard in which a number of current-model trucks were evaluated. A common defect was insufficient range of adjustability in the seat, either horizontally or vertically. Again, important controls were often placed too far away. For example, in one model only 5 percent of the drivers could reach and operate the handbrake from the normal driving position.

Clearances were frequently inadequate; in one model only the shortest 40 percent of drivers could get the knee under the steering wheel when raising the foot to the brake pedal. In another, this clearance was so small and the gear shift was so close to the steering wheel that the tallest 15 percent of drivers could not raise the foot to the brake pedal, by angling the knee out to the side of the wheel, without first shifting the gear lever away to the right. Figure 5 shows the distribution among truck and bus drivers of three body dimensions important in driving, to illustrate the kind of information that may be used in designing to "fit" the drivers.

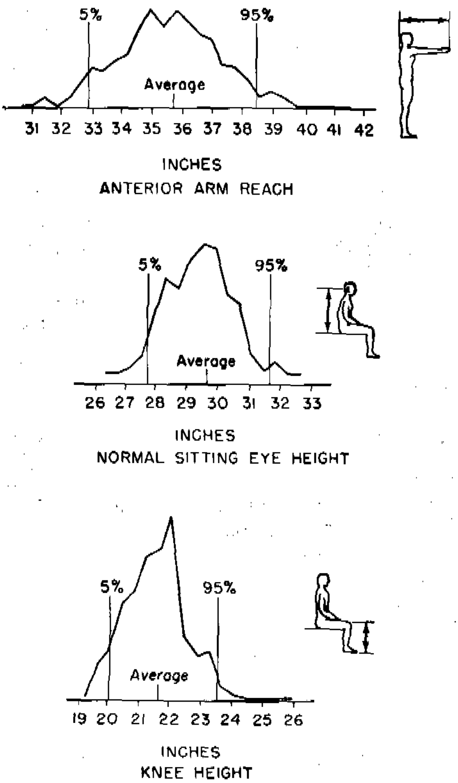
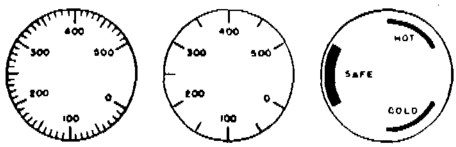
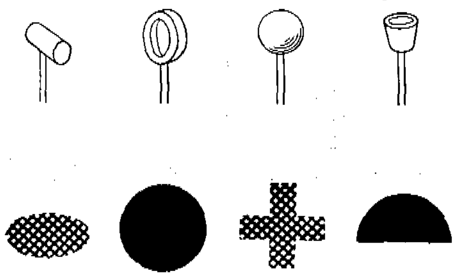


FIG. 5. Variations among approximately 400 truck and bus drivers in body-size dimensions important in driving.

Inadequate vision from motor vehicles onstituted a common problem, especially or the perception to the side and to the rear. Vithin the car or truck, instruments were requently designed or placed so that they ould not be read accurately and rapidly. nobs and switches were sometimes identcal in design and could not be distinguished om each other readily. Often they were located that they could be operated advertently or by mistake. For example, driver of one make of automobile had a serious accident while traveling at high speed during the night when he inadvertently shut off his headlights with the belief that he was pushing the knob for the cigarette lighter. Many examples illustrating such errors in design are found in the reports from studies carried out by the Harvard School of Public Health.



Baker and Grether have demonstrated visually the principle of designing dials so that they can be read accurately and rapidly. Shown are 3 dials, 2 of which require the operator to interpolate between numbers on the scale. The third gives the necessary functional information at a glance.



Examples of the way in which knobs and handles can be shape coded to prevent the inadvertent operation of controls through mistaken identity have been developed by Jenkins and Sleight. Accurate visual discrimination can also be made when there is good color or contrast with the background.

Certain design features are especially important as causes of injuries to drivers and passengers in crashes. It is recognized that the crash and impact forces of a large proportion of fatal automobile accidents were actually within the body's physiological limits of survival, if the momentum of the body had been properly checked and the forces dissipated. A large-scale study of injury in relation to the structural features of cars and the circumstances is now based on the analysis of 8,000 cases per year.

This study was initiated at the Cornell Medical College by the Commission on Accidental Trauma and has received substantial additional grants from two of the major automobile manufacturers.

An early finding in this study was that being ejected from the car considerably increases the possibility of injury or death. It was estimated that a reduction of 5,000 fatalities in the United States could be achieved each year by such means as improved door latches and the use of safety belts. Based on analyses of injuries sustained by 3,450 persons in 2,000 accidents, certain structures have been incriminated as important sources of injury to vehicle occupants. In addition to door latches that open and permit ejection, they are in descending order: the steering wheel and column, the instrument panel, windshield, top edge of front-seat back, door structures, and the lower part of the back of the front seat.

Another analysis in the Cornell study indicated that speed, when lower than 50 mph, is only partially correlated with the severity of injury. At the lower speeds especially, the design features in the car and the factor of ejection are of greater importance than the rate of travel at the time of the accident.

* * *

Host-Environment Relationships in Accidents

Many factors in the environment may influence the efficiency and safety of the operators of vehicles. Illumination, bad weather, and toxic agents such as carbon monoxide are important in highway safety, while temperature, humidity, and ventilation are significant under extreme conditions. Noise and vibration are known to be excessive in certain types of highway vehicles. In aviation, the development of the pressurized cabin is of special interest since it affords an unusual illustration of the relationships between the host, the agent, and environmental factors affecting both health and safety.

Limits have been worked out for many of the environmental variables to show their influence on those who fly in air transports in terms of zones of comfort, discomfort, physiological harm, or intolerability. These are given schematically in figure 6. If the values in the innermost of the three concentric circles are adhered to, perfect comfort is assured. The second circle represents maximum limits for comfort; hence if these values are exceeded discomfort will result. The outer circle presents values which would be physiologically harmful to the individual if they were reached or exceeded. While the chart has the advantage of brevity and clarity, it may be misleading if the values are accepted too rigidly, for many of them are interdependent. A comfort limit for noise, for example, is apt to be meaningless unless it is related to both frequency and duration. Similarly, the annoying features of vibration are functions of both the displacement amplitude and the frequency. The limits shown for carbon monoxide will be too high if persons are engaged in physical activity or are exposed to the gas while at high altitude.

Efficiency of Vision: A significant factor in host-environment relationships is efficiency

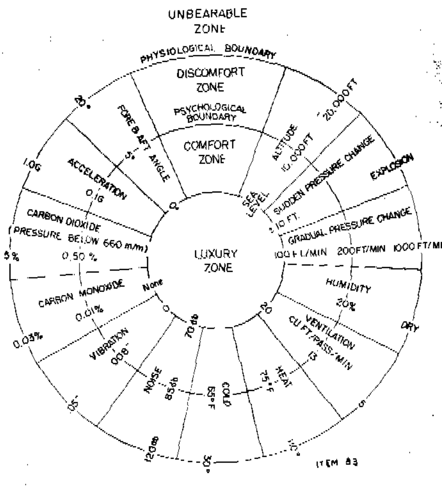


Fig. 6. Comfort and tolerance limits for physical variables of the environment.

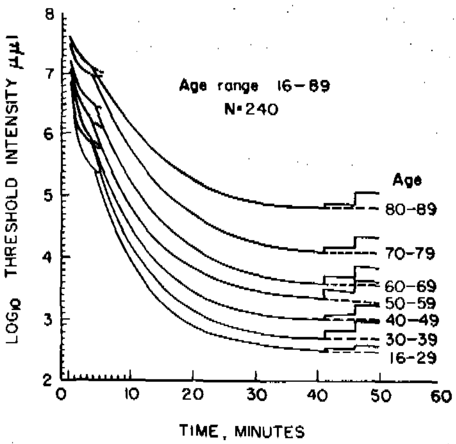


FIG. 7. A comparison of the average dark adaptation curves for eight age groups, each curve indicating the greater sensitivity of the retina as it becomes adapted to darkness.

of vision. In the United States, accident rates per unit of travel are three times higher at night than during the day. Presumably, this is due partly to the lower visibility provided by night-time illumination, a contention supported by lower accident rates on lighted highways and by the reduction in rates following improvement of illumination on particular highways.

Older drivers are especially vulnerable in this connection, since the ability to see at low levels of illumination decreases regularly with increasing age. This effect is quite noticeable by middle age and becomes very marked in the elderly. We have calculated that for a dim light or object to be just seen by an eye in the dark, the illumination must be doubled for every increase of 13 years in age.

The use of tinted windshields by older drivers may present special hazards at night, since the glass further reduces visibility by reducing the intensity of light reaching the eye. Figure 7 shows the increase in light for threshold perception as age increases. Slightly more intensity was needed at all ages when test lights were seen through ordinary clear windshield glass, which here is introduced at 41 minutes. When tinted glass is used, a larger increase in intensity is required. This illustrates in quantitative terms the importance of the interrelationship between factors relating to the host, the agent, and the environment.

Toxic Agents in the Environment: Exposure to subclinical concentrations of carbon monoxide frequently leads to effects which may not be noticed by drivers. Even very small amounts of this gas breathed into the lungs are taken into the blood stream, resulting in some degree of oxygen deficiency in the tissues. Early symptoms are lowered alertness, difficulty in concentration, slight muscular incoordination, and a mental and physical lethargy. Reduction of night vision can be demonstrated as one of the first effects. These initial symptoms are not permanently injurious, but owing to their nature, they may easily cause hazardous situations. Although, in general, exhaust systems have been improved to prevent the leakage of fumes, appreciable concentrations of this gas have been found in the passenger compartment when the car stands with motor idling or moves slowly in dense traffic. Drivers should be well indoctrinated on the need for flushing vehicles with fresh air in such circumstances.

In addition, drivers and airmen should know that certain conditions will intensify the effect of carbon monoxide from engine exhaust. For example, the effect of carbon monoxide is obviously more pronounced the higher the altitude. If the blood of a chronic smoker at sea level already contains 5 to 7 percent carbon monoxide absorbed from tobacco smoke, he is affected as if he were a nonsmoker at an altitude of 7,000 or 8,000 feet. Figure 8 shows the combined effect of carbon monoxide and altitude as expressed in terms of the altitude producing an equivalent degree of anoxia. Thus, a person at sea level exposed to air with a partial pressure of 0.06 carbon monoxide would be affected to the same extent as if he were breathing uncontaminated air at 12,000 feet. If other oxygenation-reducing factors are present, such as the use of alcohol or

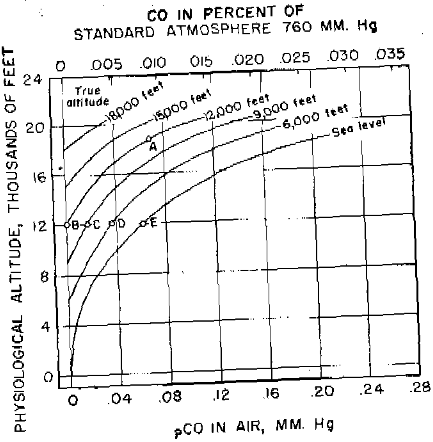


Fig. 8. The combined effect of carbon monoxide and altitude expressed as altitude producing an equivalent degree of anoxia.

certain medicines (sulfanilamide, barbiturate, or acetanilid, for example), the various factors may combine in their effects, resulting in a significant state of oxygen deficiency seriously jeopardizing safety.

* * *

Conclusions

Accidents now rank above disease as the chief cause of death and disability to many segments of our population, and now constitute a major threat to the well-being and health of our people.

The accepted function of medicine has been the treatment of disease and injury. Just as the province of medicine has been extended to include the prevention of disease, it is proposed that the prevention of accidental trauma should be a responsibility of preventive medicine and public health.

When accidental trauma is considered a noncontagious mass disease of epidemic proportions, the epidemiological approach should be applied to the study and control of injuries since similar biological principles are involved. An interdisciplinary approach is a basic requirement in this because multiple causation is found in most accidents.

The causes of accidents may be identified in the interactions between the host, the agent (or equipment), and variables of the environment. Human factors are especially important, and the physician can contribute effectively in the analysis of accident causes because of his background in the biological sciences and his knowledge of human behavior. He can indoctrinate his patients and teach while treating.

Factors of significance to the host in the control of accidental trauma include not only those which determine suitability for a given task such as driving a vehicle or piloting a plane, but also such factors as age, training, and, particularly, personal adjustments. The most promising approach to identifying the accident repeater is based on the concept that "a man works, or drives, as he lives."

The control of various temporary host factors such as fatigue, emotional problems, effects of alcohol, and the influence of disease is highly important. Periodic medical examinations and adequate programs of health maintenance can play a significant role in improving safety both in land and air transportation.

Biotechnology and human engineering should be applied to the design of equipment in order to achieve a closer integration between the operator and his equipment.

* * *

Host-environment relationships also have implications for safety in transportation because of the influence upon the individual of physical variables such as the level of illumination, the temperature and humidity, and exposure to carbon monoxide and other toxic agents. Data have been worked out for each of these variables outlining the zones of comfort and discomfort and the ranges where human performance is adversely influenced.

* * *

In conclusion, the physician or the public health officer has a direct responsibility for the prevention of accidental trauma. He may contribute most effectively by hi aid in carrying out controlled experimental and clinical studies, epidemiological surveys, and by collaborating with specialists in other biological sciences, engineers, and administrative officers in a combined approach to this problem.

The introduction to the foregoing paper emphasizes the recent increase in the relative importance of accidents as a source of human morbidity and mortality and the particular importance of accidents in relation to various forms of transportation. McFarland categorizes the factors in the causation of these accidents in terms of the host-agent-environment triad discussed in the first paper in this chapter.

In fact, he regards the application "of the epidemiological approach in determining the fundamental physical, physiological, and psychological characteristics of the host" as "a basic step." He later discusses the same approach applied to the pertinent characteristics of the agent, the environment, and their interactions. Unfortunately, the designation of "vehicles and equipment" as the agents required by this model is unsatisfactory for the reasons cited above.*

McFarland is especially concerned with the interaction of man and his mechanical and physical environments. The study of man-machine "systems" has, in recent years, come to concern designers of complex modern equipment, particularly aircraft, not only for the prevention of accidents but also for increasing the speed and efficiency of the interactions involved and decreasing operational errors.[6] To the extent to which such errors prove injurious to either the operator or the system, their effects fall within the purview of this volume, but the subject is far too complex for discussion in these pages, and the reader is referred to a standard text in "human engineering."[19] The interested reader should also see reference 6 for a discussion of "fail-safe" mechanisms.

Illustrating his discussion with examples drawn widely from military and civilian experience, McFarland documents the ever-present need for focusing attention on many very specific characteristics of those involved in the accidents under study. Of particular interest in this context is his statement that "thus far no single characteristic of drivers has been identified which accounts for [the initiation of] a large proportion of accidents on the highway."† This has proved a disappointment

* As has been stated elsewhere, the failure to recognize the essential role of abnormal energy exchanges in the production of unexpected injuries has led to many statements that motor vehicles and other striking objects are the agents required by this model. It is now seen that they are *not* the agents, but, rather, are the vehicles or vectors that transmit the agent to the host. Similarly, an electric line is a vehicle of electricity, a hot stove a vehicle of thermal energy, a poison container a vehicle of its contents, a poisonous plant or venomous animal a vector of its toxin, and a food that contains a harmful radioisotope is a vehicle of radiation. See Chapters 4 and 9 and references [illegible] and 6.

† Subsequent research on fatal motor vehicle accidents showed that in the area of study (New York City) large differences in blood alcohol concentrations discriminated between the accident-involved and the noninvolved in about one-half of cases (see the McCarroll and Haddon selection in Chap. 3). There is consistent evidence coming as well from other areas.[21] However, the relative prominence of this factor in no way diminishes the importance of considering accidents (including those initiated by the use of alcohol) as the common end results of the operation of many complex and varied factors. The immediate causes of the injuries received are, however, much less numerous, as noted above and in Chapter 9.

to many who, for various reasons, would prefer to regard the initiation of highway accidents or, for that matter, of accidents of other types, as the result of relatively simple precipitating causes, widely active. It is important to note, however, that the damage produced in highway accidents, whether involving animate or inanimate structures, is almost invariably the result of mechanical energy transfers, and that without such transfers no such damage can be produced. The rare exceptions usually involve thermal or electrical energy, or interferences with normal energy exchange produced by submersion or carbon monoxide (see Chap. 9).

Although this selection includes many points that might be discussed at length, only a few can be considered here. With respect to McFarland's discussion of the accident rates of trained and untrained drivers, subsequent research has indicated that the difference in rates may be due, at least to some extent, to preselection of those who receive such training. For example, one investigation[20] has found that those who voluntarily enrolled for such training were significantly different in their psychological characteristics. In addition, social differences might also be anticipated. Thus, for example, those registering for such courses may do so because, unlike those who do not register, they do not already drive and have less opportunity to do so once they receive their licenses. Until differences of this type have been thoroughly investigated, it will not be possible to determine, despite its seeming reasonableness, the extent to which "driver education" influences the accident experience of those who receive it. This point, which is widely overlooked by nonresearch workers concerned with highway safety, illustrates the need for caution in the interpretation of gross differences in accident rates.

Another group of characteristics of the host, predominantly of a sociological nature, is summarized in Figure 4. These represent a research area that needs considerable further attention, despite the many and varied contributions cited in Chapters 5 through 8. It seems probable that the further investigation of social variables will prove as productive as these initial results suggest.

This discussion also notes the need for the study of the exact risks, if any, of drivers with various specific medical and related characteristics which might be presumed, on the basis of speculation, to involve increased risk. It points out that "arbitrary prohibition of driving for all those afflicted with certain conditions would be needlessly restrictive and unfair to many persons. . . . " This calls attention to another accident research problem that has received inadequate investigation except in the work of Jacobs *et al.*[22]—namely, that one of the basic considerations in urging restrictions for pilots, drivers, and others is the number of excess accidents that might be expected to be prevented per individual restricted (or, in most actual situations, per thousands of operators restricted, since the gains are theoretically quite small).‡ In the case of drivers, taking them off the roads and making pedestrians of them might on balance actually increase the resultant mortality and morbidity, another of the many points in this field that require investigation.

McFarland presents considerable evidence as to the pertinence of various attributes of the host—body dimensions, medical, psychological, social, and physiological

‡ Factors to be considered in reaching decisions as to motor vehicle operator restrictions have been summarized in reference 9.

characteristics, and many others. It is often discouraging to those new to the accident field that so many variables are known to play some part in the initiation of some accidents. But unless this is kept in mind, the same narrow approaches that have been previously discussed tend to be overemphasized, and the findings that result from them are proffered as explanations of the initiation of accidents of all types.

The same points are well illustrated by McFarland's discussion of a number of the characteristics of the environment. Figure 6 indicates a few of the bewildering array of such parameters which are known to have occasional importance. Although Figure 6 emphasizes the physical characteristics of the environment, including humidity, temperature, noise, vibration, carbon monoxide* and dioxide concentrations and others, the biological, social, and psychological environments are also of major importance, as is emphasized elsewhere in the paper and in subsequent chapters of this volume.

By this point the reader should be quite aware of the considerable complexity and number of variables pertinent to accident research. Since few individuals or research groups possess sufficient familiarity with all of this panorama of variables and with the ways in which data may be collected with respect to each of them, he should also recognize that there are subtle pitfalls in work outside of the areas of his special competence. This is but one additional reason for caution in extrapolating to the entire field of accident causation the results obtained through analyses of one type. This complexity and the difficulty of drawing conclusions from general data raise questions as to the means by which data may be collected for more specific research purposes, the subject introduced in the next chapter.

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* The substantial uptake of carbon monoxide from cigarette smoke has been overlooked by many who have speculated about its possible pertinence. For documentation of this uptake see references 18 and 23.

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