Section of Epidemiology and State Medicine

President—Professor ROBERT CRUICKSHANK, M.D., F.R.C.P., D.P.H.

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Epidemiological Methods in Preventive Medicine

PRESIDENT'S ADDRESS

By Professor ROBERT CRUICKSHANK, M.D., F.R C.P., D.P.H.

THE title of this Presidential Address caused me some thought for although I knew what I wanted to talk about, it seemed advisable to let any prospective audience also know what was in my mind. You will remember the advice given by the sage to the young lecturer: Tell them at the beginning what you are going to say, tell them in the middle what you are saying and tell them at the end what you have said. It may be well, then, to define more fully and precisely the meaning of our title. The constitution of this Section of Epidemiology enjoins us to study endemic and epidemic diseases. Epidemic means literally "among the people", and an epidemic disease is defined by the Oxford English Dictionary as a "disease which is prevalent among a people or a community at a special time and produced by some special cause not generally present in the affected locality". Epidemiology may accordingly be defined as the study of disease as a mass phenomenon, the unit of observation being a group of people, not a single individual as in clinical medicine. The fuller, and often quoted, definition set down by August Hirsch in 1883 states that "epidemiology is a science which will give firstly a picture of the occurrence, the distributions and the types of the diseases of mankind, in distinct epochs of time and at various points of the earth's surface; and secondly will render an account of the relation of these diseases to the external conditions surrounding the individual and determining his manner of life".

There is no particular mention of infectious diseases in these definitions, and yet today many of us think of epidemiology as being concerned specifically with the study of diseases transmissible by a known or suspected viable agent. It is true that through the ages epidemiology has become particularly associated with the group of "communicable diseases", largely because these infections have been the most prevalent and disastrous of the epidemic diseases. But it is interesting to note what Dr. Babington, the first President of the Epidemiological Society of London, said in 1850, while cholera and typhoid, scarlet fever and diphtheria were still plagues in our land. "Epidemic febrile diseases", he said, "will no doubt be the subject of our chief study as being immeasurably of the most common occurrence and most fatal in their results; but we must not forget that there have in times past existed, and there may exist again, epidemic visitations of diseases of a nervous character, as for instance tarantism, the dancing mania, and other allied infections; of a hæmorrhagic nature as apoplexy which has been known to exist epidemically in Holland; and even of a cachectic nature as leprosy and scrofula, in which diseases the endemic character has occasionally passed into the epidemic form." There was, of course, no hint in those days that leprosy and scrofula might be due to some transmissible agent for this was still the pre-bacteriological era. A little later, in 1862, the Epidemiological Society defined epidemic as "including the diseases classified as zymotic or miasmatic; many local and constitutional diseases which at times assume an epidemic character; and certain endemic and indigenous diseases such as goitre, pellagra and beri-beri which are peculiar to regions and countries".

There seems to be, then, good reason for adopting a broader definition of epidemiology than has become associated in the minds of many of us, and indeed this more general connotation has already come into use for we read in our medical journals about studies on the epidemiology of hypertension and heart disease, peptic ulcer and cancer, accidents and suicides. However, lest I offend reactionary susceptibilities I have used the term "epidemiological method", since it is technique or methodology that shall be our main concern here. The term Preventive Medicine is used in an all-embracing sense to cover Social Medicine and the Public Health, and indeed medicine generally, for surely the objective in all our medical researches is towards ways and means for the prevention of disease.

THE EPIDEMIOLOGICAL METHOD

Advances in our knowledge of the prevention and treatment of disease have depended on three main methods of investigation—the clinical, the laboratory, and the epidemiological. The clinical method was concerned at first with careful observation by eye and ear and touch of the signs and symptoms in the ill patient, and led to a separation into different disease entities. Sydenham, Bellonius and other French physicians were among the pioneers in this field. Later, various tools like the

stethoscope and the clinical thermometer helped in more precise diagnosis and now the clinician uses a whole battery of ancillary aids. He has also developed, under the inspiration of men like Sir James Mackenzie and Sir Thomas Lewis, what is called clinical science or bedside pathology where the patient or human volunteer is himself the experimental animal.

I need not elaborate the contributions which the laboratory has made to medical knowledge. The approach here is that of the experimentalist, and the methods used have been many and varied. The starting point has often been a clinical observation which has led to a hypothesis and that in turn has been put to the test by planned experiment. Careful observation in experimental work has often led to new and unexpected discoveries in which there is less element of luck than is sometimes supposed, for it is the trained mind and observant eye that gets these "lucky breaks".

The epidemiological method is apparently quite different from the clinical and laboratory approach. It depends basically on the collection of data about a community and its environment, but as Wade Hampton Frost has said in his introduction to the reprinting of John Snow's two classical papers "epidemiology at any given time is something more than the total of its established facts. It includes their orderly arrangement into chains of inference which extends more or less beyond the bounds of direct observation. Such of these chains as are well and truly laid guide investigation to the facts of the future; those that are ill-made fetter progress. But it is not easy, where divergent theories are presented, to distinguish immediately between those which are solid and those which are merely plausible". That Snow was among the first to lay the chains well and truly—what has been called a "shoe leather" rather than an "arm-chair" epidemiologist—is indicated by his use of the spot-map, probably for the first time, to indicate the distribution of the cholera cases in the Broad Street district, and his later demonstration, by visiting every house where a case of cholera occurred, that the infection was being spread by one company's water supply and not by another supplying the same area (Table I).

TABLE I.—CHOLERA DEATHS—LONDON 1854

Southwark and Vauxhall water supply	71 per 10,000 houses
Lambeth water supply	5 per 10,000 houses
Rest of London	9 per 10,000 houses

This approach to medicine is not after all so different from the clinical approach where the ill-made chain of inference based on careless or inadequate observations easily leads to erroneous diagnosis, whereas the experienced diagnostician who has developed a thorough method of examination, supported if need be by ancillary aids, is much less likely to make mistakes.

History supplies numerous examples of mistakes in epidemiological diagnosis, particularly in the days when the collection of data was rather haphazard and there was little appreciation of the need for controlled statistical analysis. There was the famous controversy, in which Noah Webster, the father of the dictionary, took an active part, as to whether yellow fever in Philadelphia was a native or an imported disease. Even the "great sanitary awakening" in the last century was based on an erroneous conception of the relationship between dirt and disease. It was because of John Snow's infinite capacity for painstaking observations and for critical analysis of the marshalled data that Frost developed such an admiration for him, and Frost himself, perhaps more than anyone else, has helped to transform epidemiology from a speculative philosophy to an analytical and productive science. I would recommend to any budding epidemiologist that he read carefully through the Papers of Wade Hampton Frost (1941) and he will find there the most practical demonstrations of the development of epidemiological concepts and methods.

The basis of all epidemiological enquiry is of course the vital statistics supplied by the practitioner and the Medical Officer of Health and analysed by the Registrar-General. The collection and dissection of vital statistics is, as Ryle called it, social pathology and we may be proud that the development of biostatistics has been led so ably by pioneers in this country—I need mention only John Graunt with his London Bills of Mortality, William Farr who supplied the ammunition for John Simon and the other public health reformers of the nineteenth century, Francis Galton and Karl Pearson who introduced new statistical tools or sharpened the old ones, and in our own time such stalwarts as John Brownlee, R. A. Fisher, Major Greenwood and Bradford Hill.

The social post-mortem examination, like the individual autopsy, depends on team work; on the one hand the clinician, the morbid anatomist, bacteriologist, biochemist, &c.; on the other, the practitioner, M.O.H., the statistician, the mathematician and so on. But the objectives are quite different; in the individual case, post-mortem analysis leads to better diagnosis and better treatment; in the community, social pathology leads to epidemiological enquiry and public health measures to prevent or control disease. The two methods are not mutually exclusive; many of the older clinicians were also good epidemiologists. But the modern physician becomes so engrossed in the complicated minutiæ of diagnosis and treatment of disease in the individual patient that he has no time for the broader issues. John Ryle changed from clinical to social medicine because he felt that the medical profession was becoming less surely attuned to some fundamental human needs—the deeper personal needs of the individual and the broader social needs of the community. Fortunately, we have a small but growing band of clinical workers who are carrying on the torch.

Medical Ecology

Epidemiology, then, by our broader definition, is concerned with all the factors contributing to mass disease, and these factors may be considered under three components—the ætiological agent, the host and the environment. This approach to disease in the community might be called medical ecology.

Thus, in studies on tuberculosis, we no longer think of the tubercle bacillus as being *the* cause of the disease; it is one of the causes with host resistance and environmental conditions playing a major role in determining the severity of the clinical infection. Besides the more obvious parasitic or biological agents of disease, there may be physical or chemical agents in extremes of heat and cold, tools causing mechanical injury, chemical poisons like lead and arsenic, deficiencies of hormone activators and vitamins like iodine and niacin.

The host's reaction to the ætiological agent will vary according to his inherent or natural resistance on the one hand and his acquired resistance on the other. Race, age, sex, heredity, nutrition, &c., all play their part. Tuberculosis behaves quite differently in the white and coloured races. Measles is a disease of early childhood in most countries since children are highly susceptible to the virus, but after the attack maintain a high resistance for life. Young children are much less susceptible to the typhoid bacillus so that typhoid fever is a rare or atypical disease in early life and is seen in its characteristic form in adults. The concept of infection as a host-parasite relationship in which both parties are primarily concerned to go on living and multiplying, has been developed by such protagonists as Theobald Smith and Burnet, and is now well established in bacteriological teaching. As a rather complex example, in talking of typhus, I tell the students of Zinsser's plea that we shed a tear for the apparent villain of the piece, the poor louse which, in conveying the rickettsia from man to man, suffers a 100% mortality while we escape much more lightly.

In like manner host resistance to disease will be affected by anatomic, metabolic and mental derangements. Nutritional status may determine the incidence of fractures and rickets which are much less common than half a century ago, whereas the stress and strain of modern life is apparently associated with an increasing incidence of peptic ulcer and cardiovascular disease, and the occurrence of motor-car accidents has been shown to have a direct relationship to the mental state of the driver.

Besides recognizing this interrelationship of ætiological agent and susceptible host in the disease process, the epidemiologist is very cognizant of the effect of environment as a contributory factor. Environment is a composite of many elements. The physical effect of climate and weather on the seasonal and geographic distribution of many diseases has long been recognized. Hippocrates in his great epidemiological treatise "Airs, Waters and Places," tells us that "hot winds cause poor appetite, derangement of the digestive organs, flabby physique: in man they lead to dysentery, diarrhœa and the ague with pleurisy and pneumonia rare. Cold winds make men sinewy, spare and costive: they conduce to pleurisies and acute diseases".

We have come to accept the seasonal distribution of the respiratory and intestinal infections as commonplace, but have we enquired enough into the manner in which these climatic factors operate, and have we studied sufficiently the effect of the individual components that make up climate—temperature, humidity, wind velocity, rainfall, sunshine and fog? Why, for example, is the young child's resistance to respiratory infection so markedly affected by sudden drops of temperature, and why are typhoid fever and poliomyelitis autumnal diseases in countries with temperate climates? In this last connexion, the recent epidemiological researches of Armstrong (1950, 1951) on the relationship of humidity to the incidence of poliomyelitis are very interesting and suggestive. Armstrong's thesis is that respired air is warmed to a temperature around 90° F. and through absorption of moisture from the upper respiratory mucosa, its relative humidity is raised to approximately 90%. When cool, dry air is breathed, the mucosal secretions may be stimulated and dried and in this way interfere with the establishment of poliomyelitis virus which in his view has its infective reservoir in the upper air passages. When warm, moist air is breathed, there is no such hindrance to the entrance of the virus. Examination of the seasonal incidence by weeks or months of an outbreak of poliomyelitis in the Washington area in 1950 showed a remarkable correlation between peaks of incidence of the disease and variations in the relative humidity of the air warmed to a temperature of 90° F. with a lag period of two to three weeks in the occurrence of the poliomyelitis cases which would correspond with an incubation period of seven to fourteen days. It was further shown that only after the relative humidity of the air, warmed to 90° F., rose above 27–28% in June did cases of poliomyelitis begin to occur, and there was a rapid fall in incidence three weeks after the humidity fell below this level in October. Armstrong therefore suggests that it may be possible to predict some weeks ahead the occurrence of an outbreak of poliomyelitis, if it is known that the virus is already present in a susceptible community.

I may, perhaps, be allowed to mention here a prophecy of a rather different kind. Dr. John Gordon of Harvard has told me that when he talks to his Public Health class in November he always warns them to look out for an epidemic of automobile accidents on or about a certain date in December; for around that time the first fall of snow invariably comes to Boston and the treacherous roads, plus the unprepared drivers, precipitate a marked increase in the accident rate.

Besides the climatic factor, there are usually also biological and social components in the environmental contribution to disease. On the biological side we must consider the whole economy of plant and animal life. The potato blight in Ireland had disastrous effects on human life and health, and rice famines have decimated by disease whole communities in India and China: even the present-day outbreaks of fowl-pest and foot-and-mouth disease could seriously curtail our limited supplies of protein. Plants, animals and insects may also act as reservoirs of infectious agents that are injurious to man. The epizootic of rat plague that precedes the human epidemic is well known to us, while malaria is being stamped out most efficiently in many lands, not by a direct attack on the parasite but by extermination of the intermediary host, the anopheles mosquito. Bovine tuberculosis and brucellosis in man are dependent on infection in the domestic cow and goat; vermin not only make inroads on our food supplies but also spread various diseases among us.

It is, however the social component of environment which has come under particular scrutiny in recent years. We have long known of the association between poverty and certain infections like tuberculosis and bronchopneumonia and the influence which social class has on the mortality rates of common childhood fevers like measles and whooping cough. But the factors within this component, social environment, embrace not only housing and clothing and food but also education, parental care, work and leisure and the whole way of life. Many of the prevalent diseases of to-day are linked to the social background; peptic ulcer, cardiovascular disease, chronic rheumatism, the visceral neuroses, psychosomatic disorders and accidents all have social components in their ætiologies, although these ætiological factors have not yet been sufficiently emphasized or analysed.

The point to be stressed is that most diseases have a plurality of causes, and the epidemiological method of enquiry is concerned to determine the relative importance of these various causative factors in a particular disease. In some instances, the agent of disease may be the most important factor as when a particularly virulent variant of the influenza virus wipes out thousands of our healthy young adults: or lowered host resistance may allow a less virulent strain of the virus to take a heavy toll of life as happened among the old populations of Liverpool and Southport in 1950. Or the complex environmental factors may play the predominant role as Villemin long ago recognized was the case in tuberculosis and as we are learning about many of our modern ailments. These various components of disease have a relative and varying weight which needs measurement and this is the function of the epidemiological method which is primarily concerned with ætiologies.

Epidemiological Dynamics

Disease in a community, like disease in the individual, is a dynamic not a static affair. It also, like individual disease, shows a gradation in its departure from the normal or healthy state. But it is just as difficult to define a healthy community as it is to define a healthy person. Obviously, we must base our standard of health on observations made on a reasonable number of apparently normal persons or communities. The resultant will not be a superman or a wholly healthy community but it will serve as a standard or control, against which we can measure abnormal or disease processes. Similarly, this standard will be the yardstick against which particular efforts towards the prevention or control of disease can be measured.

As an example, it would be generally agreed that in any modern civilization a sizeable proportion of the community will develop and probably die of malignant disease. But if some readily recognizable cancer, like that of the breast, is diagnosed and treated early, it might be hoped thereby to reduce the deaths from this particular cause. With that in mind, a number of health authorities, e.g. the State of Massachusetts and the Province of Saskatchewan, have embarked on large-scale and expensive campaigns for the early recognition and cure of accessible cancers, and are claiming good results from their efforts. McKinnon (1952) has, however, critically examined their statistics and has assessed the mortality rates in these states against those of other states and countries which have not adopted extensive cancer campaigns. His analysis indicates that the mortality rates from breast cancer in the different age groups show identical trends in the different states and countries from which comparable statistics are available. This does not mean that we should relax our efforts to recognize and treat cancer as early as possible but it does indicate that the more malignant breast cancers metastasize early and that the public may be misled about the value of propaganda for cancer control.

The biological gradient.—Just as health is compounded of a range of degrees of health, so most morbid processes show a gradient in the degree of severity—what Gordon (1950) calls the "biological gradient". We see it best, perhaps because we have studied it most, in the infectious diseases. The gradation from the characteristic clinical infection through mild, atypical forms to symptomless carriers of the infecting pathogen is well recognized but even in infections where most of the susceptible community suffer clinical attack, as in measles and whooping cough, we can see this biological gradient. If this gradient is carefully measured in the natural disease, we can assess the value of any prophylactic procedure, for example gamma globulin or pertussis vaccine, by the way in which it alters the gradient. Thus, in the whooping cough vaccines trials sponsored by the Medical Research Council, two groups of children whose average age was one year and who in other respects

were remarkably identical, were compared as to the incidence and severity of whooping cough over a period of two and a quarter years following vaccination. The vaccinated children showed a ratio of about 4 : 1 completely protected compared with the control group but in addition the biological gradient of the infection among those vaccinated was quite different from that of the natural infection (Fig. 1).

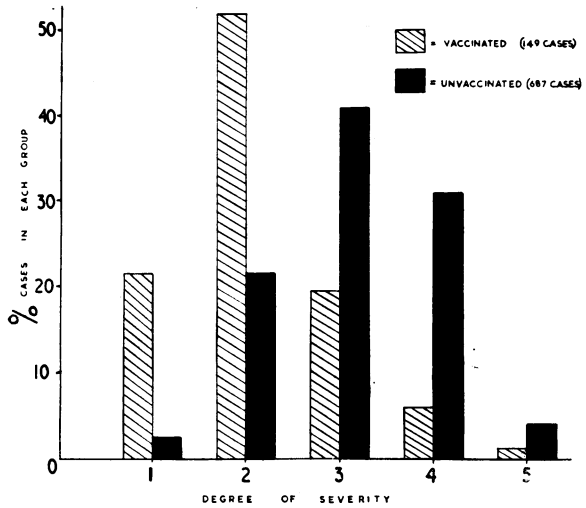

FIG. 1

MAJOR "REASONS FOR CHRONIC INCAPACITY" IN INSURED PERSONS : SCOTLAND 1936.

INSANITY	21·2
RHEUMATISM	12·6
DISEASES OF THE CIRCULATION	11·4
TUBERCULOSIS	11·2
BRONCHITIS	7·9
NEUROSIS	6·9
OTHER RESPIRATORY DISEASES	3·9
INJURIES	3·4

TABLE II

FIG. 1.—Severity of pertussis in vaccinated and unvaccinated cases. 1 = an abortive attack, with or without occasional paroxysms confirmed bacteriologically. 2 = fewer than 10 paroxysms in twenty-four hours at height of disease. 3 = 10–20 paroxysms in twenty-four hours at height of disease. 4 = more than 20 paroxysms in twenty-four hours at height of disease. 5 = attack complicated by bronchopneumonia, atelectasis, &c.

The same difference was seen in the studies of diphtheria among immunized and unimmunized communities reported by Hartley and Tulloch (1950). Indeed, it seems likely that this gradient is a common biological phenomenon in most diseases and careful observation of its characters in the natural disease will help to assess the value of any control measures. This is essentially the method of approach in the controlled clinical trials of new medicaments (*see* Hill, 1951), which has become common practice here and which, incidentally, is the envy of our American cousins.

Prevalence v. *Incidence.*—I should like to mention another dynamic factor in mass disease which sometimes leads to confusion. It is the difference between the *incidence* and *prevalence* of a disease. Incidence measures the rate of occurrence of new cases of a disease in a period of time, usually a year; prevalence expresses the frequency of existing cases of the disease at a prescribed time. Thus, a mass X-ray survey might discover approximately the same proportion of cases of pulmonary tuberculosis among the white and coloured populations of an American community but notifications of new cases and deaths would indicate that the incidence of pulmonary tuberculosis was relatively much higher in the negroes among whom the disease often runs a fulminating course.

With modern chemotherapy, which saves but may not cure patients who used to die of a progressive tuberculous infection, an increased prevalence of tuberculosis may be noted, although incidence, i.e. the occurrence of new cases, may be declining. So it is with other diseases like diabetes and pernicious anæmia where specific therapy prolongs life and leads to a greater prevalence, but not a higher incidence, of cases in the community.

Causes of death.—The dynamics of mass disease also leads to changes in the principal causes of death, and so reorientates our views about control or preventive measures for improvement of the public health. In 1901, the Captain of the Men of Death was pneumonia and bronchitis, which together accounted for approximately 82,000 deaths: there followed, in order, tuberculosis, heart disease, cancer and cerebral vascular disease. In 1949, the acute respiratory infections and tuberculosis had dropped to fourth and fifth places respectively and were superseded by the other three main killing diseases in the same order as in 1901 (Logan, 1950). The phenomenal decline in deaths from infectious diseases, which in the past half-century have fallen by 94%, has thus served to focus attention on cardiovascular disease and cancer, although we should remember that these are, for the most part, diseases of the older generation who have already made their contribution, and whose lives are less valuable than those of a younger age group. In this respect, tuberculosis, although it has fallen to fifth place as a cause of death, is still a most costly disease to the community because it causes a chronic and often fatal illness among men in the prime of life.

The changing nature of disease and the size of the problem which different diseases present may also be gauged from the register of chronic sickness which was kept as part of the pre-war Scottish morbidity statistics among insured persons, and which, it is hoped, may emerge again under the certification schemes of the Ministry of National Insurance. The Scottish figures for all workers aged 16 to 65 who had been on the sick list continuously for one year or more put insanity at the top, with rheumatism, circulatory diseases, tuberculosis, bronchitis, neurosis, other respiratory diseases and injuries following in that order (Table II).

The psychosomatic element is well represented in this list and it may be worth remembering Halliday's (1949) dramatic representation of the rise in the incidence of these diseases, while the more purely physical ailments declined in incidence and severity.

Applied Epidemiology

With the Registrar-General and the Minister of National Insurance as our guides, the application of the epidemiological method to problems of mass disease follows a basic plan which, of course, will be varied for individual needs. It involves, in order, a study of the nature and extent of the problem; a search for the causative factors of the disease and its peculiar distribution in the affected population; formulation of measures for prevention or control based on demonstrated ætiological factors; and, lastly, statistical evaluation of the results of control measures. In some diseases, rational control measures can be instituted before the agent of disease is precisely known, as Snow showed in his cholera studies and Goldberger in his pellagra investigations; in others, even when the factors of causation are defined, the application of control measures may present great difficulties if the habits and way of life of a community are not to be disrupted.

I do not propose to discuss in detail the epidemiological techniques by which these various steps are put into practice. It is essential that we should decide, as precisely as possible, what are the questions to which we want to find the answers; and it will usually be advisable to limit the questions and the variables so that the answers will be fairly clear cut. For example, we have lately begun a study of the ætiology of bronchitis and bronchopneumonia among young children in the Paddington area; and since overcrowding seemed likely to be an important causative factor in the complex environment of "poverty" we have designed our investigation to find, if possible, what part overcrowding specifically plays in the respiratory infections of infancy.

Perhaps we can best indicate the application of the epidemiological method by taking examples from different groups of disease; the communicable infections, the organic non-infectious diseases, the psychosomatic disorders, and accidental injuries.

Whooping cough.—In the first group whooping cough may be cited. Detailed studies such as those of Percy Stocks and Karn (1932) in four London Boroughs showed that 40–50% of children had had a clinical attack of this protracted debilitating infection by the age of 5 years and other information indicated that 70% of children aged 11–12 entering our Public Schools had been affected (Schools Epidemics Committee, 1938). Mortality figures showed that the infection was most severe in infancy and that death-rates were much higher in the lower than in the higher social grades, possibly because of secondary infections. There was good evidence that the agent of disease was the *Hæmophilus pertussis* which with careful cultivation on artificial media could be prevented from deteriorating into a rough non-virulent form. What was in doubt was the capacity of vaccines of this bacterium to give protection against whooping cough. The Medical Research Council therefore decided to test the prophylactic value of different vaccines on large and homogeneous groups of highly susceptible volunteer children, half of whom would be given injections of a control vaccine which could not give any specific protection against this disease. All the children were to be carefully observed for at least two years, the observers would not know which child had received pertussis vaccine and which the dummy vaccine, the severity of any clinical attack was to be graded and clinical diagnosis was to be corroborated by laboratory aids. The analyses of the first trials have been published (Medical Research Council Investigation, 1951) and show that the two groups of inoculated children were remarkably alike, that vaccination considerably affected both the attack rate and the severity of the infection, and that some vaccines were more effective prophylactics than others.

Lung cancer.—The phenomenal increase in the number of deaths attributed to cancer of the lung in the past thirty years has attracted great attention and stimulated many enquiries as to its reality and causation. Some hold that the increase is more apparent than real, being associated with a greater awareness and improved methods of diagnosis of the condition. On the other hand, Stocks (1947) has adduced convincing statistical evidence of a real increase. Between 1921–30 and 1940–44, the deaths from lung cancer among men at ages 45 and over had increased sixfold and among women of the same ages approximately threefold. Similar increases have been noted in other countries. Hypotheses about the causes of the increase (apart from better recognition) have centred round two main factors, (1) atmospheric pollution from car exhausts, tarred roads and the like, and (2) the smoking of tobacco. The study by Doll and Hill (1950) of the part which smoking may play is a good example of the application of the epidemiological method. The investigation was centred round

20 hospitals in the London area which were asked to notify all cases diagnosed as cancer of the lung, stomach, colon and rectum. These patients were then interviewed by almoners with particular reference to their smoking habits. For each lung cancer patient a non-cancer control patient of the same sex and age group in the same hospital was similarly interviewed at the same time. There were thus two control groups—one of patients with cancer of the alimentary tract, and one of non-cancer patients, which turned out to be strictly comparable with the lung cancer group except for some difference in the places of residence. Analysis of the data pertaining to 649 men and 60 women with lung cancer showed that 0·3% of the men and 31·7% of the women were non-smokers compared with 4·2% and 53·3% in the control non-cancer group. Among the smokers, 26·0% of the male cancer cases and 14·6% of the females were heavy smokers (25 or more cigarettes per day), compared with rates of 13·5% of the male controls and none of the females. There was thus a definite shift towards a heavier consumption of tobacco as cigarettes among the lung cancer patients. The possibilities that the results obtained might have been associated with an unsuitable control group, with bias on the part of the cancer patients about their smoking habits, or bias on the part of the interviewers were all critically considered and rejected. The conclusion was reached that smoking is an important factor in the ætiology of lung cancer.

The drawback to enquiries of this kind is that they are "looking back" rather than "looking forward" investigations, and Professor Bradford Hill is rightly extending the scope of this study by obtaining the smoking histories of a group of the population—the medical profession—scattered throughout the country; he now patiently, or impatiently, waits in his office to see which of us is going to die of lung cancer.

Peptic ulcer.—Peptic ulcer is a generic name for acute or chronic ulcerations of the gastric or duodenal mucosa, which has shown amazing fluctuations in its incidence and sex distribution in the last half-century. Evidence about its changing incidence and ætiology has been sought from many sources; mortality statistics, hospital clinical and autopsy records, population surveys, &c. As an example of the most satisfactory method of approach, the "forward-looking" population survey, I would commend the study of Doll and Avery Jones (1951) which makes full use of epidemiological techniques. Interesting points which emerged from the investigation were that in London 5·6% of men between the ages of 16 and 64 and 1·9% of women of the same ages have peptic ulcer; that the total number in England and Wales is around one and a half millions; and that incidence increases with age, reaching a maximum of 9·6% in men at ages 45–54 and 6·1% in women over 55. The sex ratio, men to women is 4·5 : 1 up to age 55 and after that 1·4 : 1. The expectation of developing an ulcer is almost constant, and at its maximum of 3·2 per 1,000 men, at ages 35–64, but gastric and duodenal ulcers behave differently in regard to age of onset. There is no support for the view that duodenal ulcers develop most frequently in young men.

Social class did not influence the incidence of duodenal ulcer but the occurrence of gastric ulcer was two-thirds less than expected in social classes 1 and 2 and two-thirds more in the lowest class, 5. As for peptic ulcer being an occupational disease, a high incidence among doctors was thought to be largely artificial because of refinements in diagnosis while there was no evidence of increased prevalence among 'bus or lorry drivers, shift workers or other occupational groups with the possible exception of foremen and business executives. There was a significantly low incidence among agricultural workers.

Anxiety over work, but not home worries, was an ætiological factor, but it may be that this anxiety is associated with a particular personality, i.e. the over-conscientious, hardworking, ambitious type of man who is said to be prone to peptic ulcer. You may say that many of these findings were already known to us but surely it is better to base our knowledge on observations backed by statistical analysis rather than on vague clinical impressions. Besides, studies of this kind point the way for further investigations into ætiology and towards preventive measures.

Automobile accidents.—Deaths from violence, which include accidents of all kinds but not suicides, have *not* increased in incidence in the past fifty years. Accidents are divisible into three groups—accidents in the home, on the roads, and in industry; although accidents on the roads have increased, accidents in the home, particularly burns and scalds, and accidents in the workshops have declined in incidence. With the exception of the enquiries into the ætiological factors in burns by Colebrook and others, the medical profession in this country has given little attention to the epidemiology of accidents, and we owe a debt to Gordon (1949*a*, 1949*b*) at the Harvard School of Public Health for showing us that the epidemiological approach to injury as well as to disease will lead to better understanding of ætiology and to rational preventive measures.

Accidents, of course, constitute one of our most serious economic problems, not only from the high proportion of deaths in school children and young men among whom death from violence is now the principal killer, but because of the temporary and sometimes permanent disability that results from the non-fatal accident. Accidents on the road nowadays take a high toll of limb and life, and it seems likely that epidemiological analysis would tell us a great deal about the causative factors and lead to better methods of control.

In Massachusetts, the high automobile accident rates associated with special holidays were analysed. Accidents were found to be twice as frequent in the early evening as in the morning although the same number of vehicles were involved. Certain roads and streets were found to have the highest rates. Police officers were therefore concentrated at these points at the material times, and as a result the holiday accident rate was reduced to a low level. Again, analysis of accidents according to the age of the driver showed two bulges in the curve, one in the age group 20–24 and the other in the advanced age group. In the first of these the accidents were associated with the male sex and when, instead of fines, the police authorities took more stringent measures against the foolhardy young men by withholding the driving licence for three to twelve months, the early bulge in the curve disappeared. Surely, this is epidemiology applied to the preservation of the Public Health.

In this country, the investigations into accidents in industry by the Industrial Health Research Board have included a study on accident proneness among motor drivers (Farmer and Chambers, 1939). It was found that men who had three or more accidents in their first year of driving buses had the same high accident rate five years later, while men with a low accident rate in their first year maintained their good record. Accident proneness could be predicted on the basis of certain psychological tests so that by utilizing these tests plus the performance in the first year's driving, unsuitable drivers could be diverted to other work and the accident rate reduced. It was also shown that accidents decreased with the age of the driver from 20–50 years, but showed a bump in the 50–60 age group when presumably advancing age and retarded reaction come on us imperceptibly and we still take the same risks as we did in our earlier years.

Conclusion

If I have neglected to tell you in the middle what it was I was saying, let me tell you at the end what I have tried to say. My thesis is that application of the epidemiological method is as likely to lead, and has already led, to just as important advances in medical knowledge and control of disease as result from the use of the clinical and laboratory methods. Progress in this field can be confidently predicted, since the past ten to fifteen years have seen great advances in the scope, the methods and the tools of epidemiological enquiry.

The epidemiological method is primarily directed towards ætiology, which may concern the agent of disease, the host and the environment, and the results obtained are applicable to an improvement of the public health by preventive rather than curative measures. Indeed, the epidemiological method may lead to rational control measures before the agent of disease is precisely known, as John Snow demonstrated when he persuaded the Board of Guardians to remove the handle of the Broad Street pump thirty years before the cholera vibrio was known, as we might to-day advise the Government that heavy cigarette smoking is a dangerous habit although we do not yet know its precise relationship to cancer of the lung.

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