



Industrial Medicine—An Art or A Science?¹

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To our predecessors—and their patients—a good bedside manner was of great importance and was greatly admired. Although the expression has now become debased to a cliché and is often used derogatorily it did not originally imply any lack of skill or training. Modern expressions, such as putting oneself across or projecting one's image, are used to convey the same idea of presenting one's talents to the best advantage.

This ability is still an asset in medical spheres, as it is in other walks of life. The doctor in industry has as much need of the ability to convince people that he has skill and experience as have his colleagues in other branches of medicine—or for that matter anyone else who works for a living by advising or serving his fellow men. He has to convince management, men, unions, and governments of the value of what he has to offer the individual, the working group, and society. He will do this better if he can present his advice in a manner which is acceptable—the bedside manner, if you like. But it will not be acceptable and he will not be successful as an industrial physician unless his findings are based on established fact and scientific evidence. An opinion based on nothing more than impression or uninformed judgement will not be accepted as an *ex cathedra* pronouncement of fact. The doctor in industry must exercise not only the so-called art of medicine but also the disciplines and techniques of science.

Until the First World War the practice of industrial medicine was based largely on the judgements made from the clinical examination of workers and observation of what went on in the factory. There were few scientific methods such as we use today to assess risks and evaluate preventive measures.

How successful were the early practitioners of industrial medicine in combating occupational disease and in promoting the health of workpeople?

Despite their limited facilities they had many signal successes, some of which were achieved in the face of opposition or indifference. The tools they had were observation, clinical medicine, and judgement, helped sometimes by inspiration and maybe sometimes by guesswork. The early successes were achieved at the stage of development of industrial medicine when the diagnosis of industrial disease was made by clinical observation alone without the aid of the sophisticated scientific tools we have today. Skin cancer, phossy jaw, lead palsy or encephalopathy, when well-established, were easily recognizable, and the cause was easily established, so that it was possible to tackle these obvious industrial diseases. For instance, the dangerous white or yellow phosphorus which had caused so much misery from gangrene of the jaw and mouth in match manufacturers was abandoned for this purpose by international agreement in 1906 as a result of the insistence of the doctors concerned, led in this country by Thomas Legge.

The next stage of the development of industrial medicine was between the two World Wars when a few doctors began to specialize in the subject. Again they had their successes. Lead poisoning was one of the commonest industrial diseases and, with the dust diseases of the lungs, was one of the chief preoccupations of the industrial physician. It has been a rare occupational disease in this country for the last 30 years (Fig. 1) and I wonder how many of us have seen a case of severe lead poisoning. This period saw the beginning of an expansion of industrial medicine which was greatly accelerated during the Second World War and which led to the practice of occupational medicine as we know it today.

Today the doctor in industry should not have to depend on the appearance of gross disease or poisoning to show that a hazard exists or that preventive measures have failed. Our aim is now directed towards the elimination of the risk from dangerous materials before damage takes place. First we press for a safe substitute but, even when one is available, it does not automatically follow

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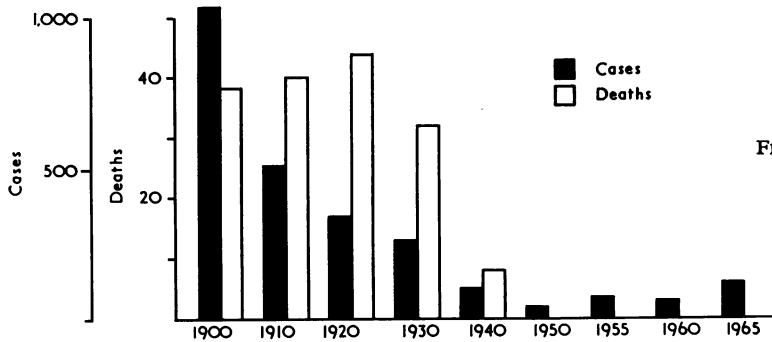


FIG. 1. Cases of lead poisoning notified to the Chief Inspector of Factories in the United Kingdom, 1900-65.

that substitution will be effected. It was possible to abandon yellow phosphorus on an international scale in 1906 because a safer alternative was available and economically acceptable, otherwise its use might have continued (Scott, 1959). By 1952 the dangerous manufacture and use of the bladder carcinogen, betanaphthylamine, had been abandoned in this and some other countries because an alternative process became available, but it is an expensive process and betanaphthylamine is still made and used in some countries. Where substitution cannot be effected, as, for instance, with lead, benzidine, and some carcinogenic mineral oils, we aim to control the environment, or, as in the case of coal dust, asbestos, and ionizing radiations, we aim to minimize the risk as far as possible. Lest this should sound cynical, may I remind you that we apply the same principles of minimizing the risk toward traffic accidents because we cannot eliminate the motor vehicle. Moreover, new risks may be introduced without our realizing or being able to foresee their danger. Therefore exposure may still occur to harmful agents, many of which are essential to our way of life, so that we cannot assume that present-day measures will be completely successful in the prevention of many of the traditional or of the new industrial diseases.

Although, with the advance of medical and scientific knowledge, orientation in occupational medicine has changed over the past 30 to 40 years towards the pre-clinical stage, it does not follow that we have lost any of the art of medicine in gaining something of the scientific disciplines. The clinical arts are not on the scrap-heap. Although radiographs, lung function tests, and comparable procedures may be displacing the stethoscope to a secondary place in the examination of the chest, as much skill is needed to interpret a chest radiograph or a patient's PCO_2 as the doctors of Tannochbrae needed to interpret the adventitious sounds they heard with their stethoscopes.

Similarly, in occupational medicine we should use the best of the old arts and science of medicine and the best of the new.

There has been a great expansion in medical science in the last quarter of a century. Since the last war electronics, the computer, automation, and the virtually new sciences of genetics, biochemistry, and immunology have been among the developments the industrial physician has had to assimilate, together with the new discoveries of industrial chemistry, physics, and engineering. What use have we in industrial medicine made of the new resources of science and how far have they helped us? I am going to review some of the recent advances in occupational medicine and discuss how the disciplines and technologies of modern science have contributed to them and how we have used and applied them.

The Physical Environment

One of the advances in industrial medicine has been the development of methods to measure, in the working atmosphere, the level of many physical agents such as heat, noise, radiation, and light and the concentration of many chemical compounds and dusts so that potential hazards can be controlled before workpeople are affected. Acceptable levels have been agreed internationally for a number of these agents and materials. These maximum allowable concentrations (M.A.C.) and threshold limit values (T.L.V.) have been reached sometimes as the result of human experience or of animal experiments, sometimes because they were the lowest attainable in working conditions, and sometimes by guesswork. As experience and knowledge increase, a more accurate assessment of many M.A.C.s may be possible.

'Normal' limits have been established for the levels of a number of toxic substances in body fluids. In industrial medicine the blood and the

urine are the fluids usually used for this purpose, but estimation of drugs in the saliva of racing animals and athletes and of alcohol in the breath of motorists are now well-known biological tests in other spheres. A 'normal' content can be defined as the amount found in persons who have had no evident occupational, medicinal, addictive or other unusual source of exposure or absorption. A more accurate estimate has been made of these normal values than has been possible with M.A.C.s because they have been established from the results of a large number of observations on people, from controlled experiments, and by the application of statistical and epidemiological techniques. Normal levels are subject to physiological variations, sometimes wide variations, depending on normal circadian rhythm, age, sex, diet, geographical location, and habits.

In mercury workers, the urinary concentration is still the most commonly used measure of absorption of mercury, but Molyneux (1966) has shown that there is a considerable circadian variation in the excretion (Fig. 2). For this reason the average daily absorption cannot be related to the excretion rate at any particular period of the day. That this is a physiological variation is largely borne out by its similarity to the circadian variation in the excretion of sodium and potassium. Because of these normal variations the results of many biological tests require careful interpretation before it can be decided, in a given case, whether a departure from normal is significant.

It should not be assumed that the mere presence of a noxious substance in the blood, urine, saliva, or breath is evidence of poisoning. For instance, lead is normally present in human blood and the range in its level is fairly wide. A raised level is obviously an indication of absorption. At some point, which varies from person to person, this

absorption leads to poisoning, and it is important that the difference should be recognized clinically. It is not possible to lay down for all compounds hard and fast biological levels at which the work may be regarded as safe and beyond which it is considered harmful. Two examples will illustrate this. Recently, on the same day in my out-patient clinic I saw two lead workers: one had a blood lead of 90 $\mu\text{g./100 ml.}$ (upper limit of normal in a lead worker is 60–70 $\mu\text{g./ml.}$) and had symptoms of lead poisoning; the other had a level of 510 $\mu\text{g./100 ml.}$ and he was very fit. The figures by themselves gave little indication of the relative clinical condition or of the urgency of the action which had to be taken. Dingwall-Fordyce and Lane (1963) recently showed that there may be a long-term risk of cerebrovascular disease in lead workers who have been exposed to high ambient levels. They found that a significantly large number of pensioners who had had a long working life and heavy exposure in a lead battery factory had died of this disease.

Occupational Hygiene Services

Occupational hygiene has by now become recognized as a science in its own right. There must be a sufficient standard of attainment for its practitioners to be recognized as a professional force, and there is need for many more qualified men to be trained so as to expand the small force of those who practise this new specialty at a professional level. It has been suggested that by the application of occupational hygiene methods the working environment can be so controlled that there will be no risk of disease or poisoning arising from adverse factors in the physical environment. That this is right in principle one does not doubt. In public health, purification of drinking water and control of infectious diseases has led to a virtual dis-

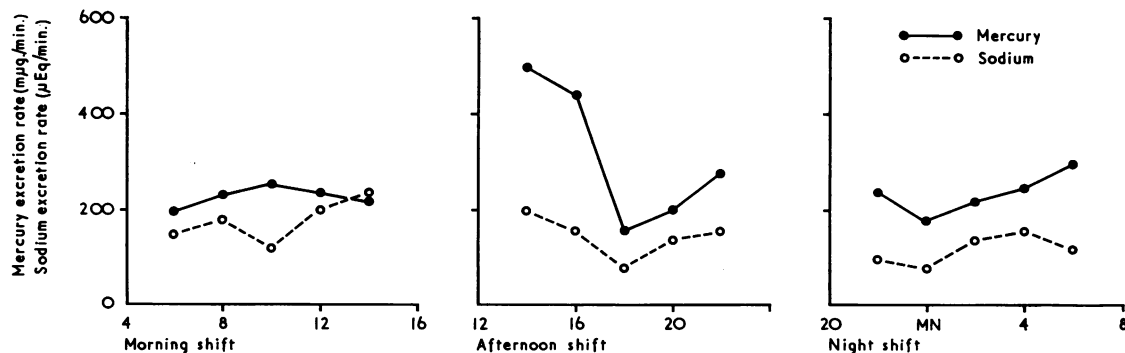


FIG. 2. Variation in rhythm of mercury excretion rate in a worker during three different shifts. (Reproduced from *Ann. occup. Hyg.*, 9, 99 by permission of the Editor.)

appearance of the traditional duties of the Medical Officer of Health in developed countries. In the atomic energy industry the application of health physics technology has kept down exposures of workmen to radiation to a safe level so that none has been affected. Unfortunately we are still a long way from attaining comparable standards throughout all industrial undertakings. Until we do, as King (1966) has pointed out, managements, doctors, engineers, and hygienists should all contribute their part and, given good housekeeping, the control must be based on a combination of clinical observation, biochemical findings, and environmental measurements.

The Psychological Environment

The psychological environment is not so amenable to exact monitoring as the physical environment, although Revans (1958) has shown how some simple measurable factors, such as the size of the working group, can afford an indication of the psychological climate of a factory and can influence sickness absence, the accident rate, and the frequency of strikes. Mental well-being is as vulnerable, but probably no more vulnerable, to adverse situations and personal relationships at work as it is in the domestic or social sphere. Few would dispute that work does more good to people's mental and physical health than it does harm or that absence or withdrawal from work carries with it a risk of mental deterioration. Great concern is being expressed in medical circles about the effect of automation on mental health. Raffle (1963) refers to the mental tensions arising from boredom, anxiety due to the difficulty of learning new techniques, and fear of redundancy in older workers. Too much leisure is widely held to be a hazard of automation and a bad thing. Lloyd Davies (1966) looks forward 'to the time when our medical resources can be concentrated on the study of fatigue, efficiency, reablement and psychological and social adjustment in the automated era now starting'.

It is by no means certain that the rapid expansion of automation will bring these fresh threats to health. Until we can assess more accurately the threat to health from boredom, anxiety, and tension we must try, from the information available, to determine to what extent mental comfort or health is likely to be threatened. The computer and automation may bring boredom to some people, but will it to many? Man will be the master of the machine and not its slave as he has been with conveyor belt mechanization. That automation will bring problems associated with too much leisure or with redundancy is even more doubtful. According to The National

Plan (1965) it is estimated that there will be a shortage of workers by 1970, and, as Bagrit (1965) pointed out in his Reith lectures, in spite of all the optimistic prophecies it may be many years before there is any great reduction in the amount of time spent at work. By that time it is likely that we may have educated ourselves to use to good advantage the leisure coming to us or at any rate to use it rather than suffer it to the point of boredom.

In addition, another new science has emerged. Ergonomics is concerned with the individual, with fitting the job to the human anatomy and to the human psychology, so there is another hope that the work to be done in the new mechanized and automated era can be done in physical comfort with as little stress to the psyche as can be contrived.

Dangerous Chemicals

It is not possible within the scope of this lecture to consider all the developments in the chemical and pharmaceutical industries or to detail the many recent advances in toxicology. Two examples may suffice to show how scientific knowledge has been applied, in one case to an old problem, benzene, and in the other to a relatively new chemical hazard, the isocyanates.

Benzene Although benzene was discovered by Faraday in 1825, Hofmann's distillation of it from coal tar in 1845 was probably the real beginning of the modern science and technology of organic chemistry. It was soon realized that benzene is a dangerous chemical. One of Hofmann's colleagues, C. B. Mansfield, was burned to death when preparing an exhibit of it for the Great Exhibition of 1851. Not only is benzene a dangerous fire hazard and an acute narcotic poison, but prolonged exposure to it has long been known to cause aplastic anaemia.

There may also be an association between benzene exposure and leukaemia. Browning (1962) considered the evidence in the literature and from that and her own experience of workpeople exposed to benzene concluded that it is a leukaemogen. No epidemiological proof has yet been adduced to confirm or refute this suggestion, but considerable support for it has been forthcoming in the work of Court Brown and his colleagues. They found structural chromosome changes in the lymphocytes cultured from the blood of workmen who had been exposed to benzene (Tough and Court Brown, 1965); these aberrations were similar to those induced by radiation which is a known cause of leukaemia. Although this does not constitute proof that benzene may cause leukaemia, it is a link in a

chain of evidence, evidence which is accumulating and may yet prove conclusive.

Benzene has been replaced where possible by safer chemicals, but it is still widely used. It is the basis for a host of substances, many harmless in themselves, which have become indispensable to our way of life—rubber chemicals, dyestuffs, pigments, paints, pharmaceuticals, and agricultural chemicals. If there is an added risk of leukaemia from benzene, it is even more important than ever that workpeople should be protected from this dangerous substance. A maximum allowable concentration of 25 p.p.m. has been set for benzene in the working atmosphere. This affords safety against acute poisoning and it is thought to be below the level at which aplastic anaemia may result, but it reflects only the amount present in a sample of air taken at a given time in a given place. Rainsford and Lloyd Davies (1965) have devised a comparatively simple method of estimating the phenolic metabolites of benzene excreted in the urine, and this provides an index of the actual absorption over a period. The speculations based on the observation of workpeople, Tough and Court Brown's laboratory study of chromosomes, and Rainsford and Lloyd Davies's chemical test for excretion demonstrate the weaving together of clinical medicine, medical science, and biochemistry into a coherent pattern of advance towards the solution of an industrial toxicological problem.

Isocyanates The isocyanates are a relatively new industrial hazard. They are used on an increasingly large scale in a number of industries for the production of polyurethane lacquers, artificial fibres, so-called foam rubber, and adhesives. Thus, they may be encountered not only in the chemical, plastics, rubber, textile or automobile industries but also in many other situations where one might not expect them. Some of the most commonly-used isocyanates are not only respiratory irritants but are also sensitizers which cause a severe asthma-like illness. Toluene di-isocyanate (TDI) is the most potent of those commonly used, but others such as diphenylmethane di-isocyanate are also sensitizers and are widely used (Munn, 1965).

The isocyanate problem demonstrates how science and medicine are involved in elucidating and preventing the effects of new chemical compounds in industry. In 1964, Scheel, Killens and Josephson induced specific antibodies in the rabbit using a TDI protein conjugate. This work went some way to indicate that the mechanism of the asthma-like reaction in humans is immunological. This finding has been taken further by Taylor (1965) here in Manchester, who has shown that antibodies specific

to TDI protein conjugate are present in the blood of affected workmen.

In 1963 the American Conference of Industrial Hygienists recommended an M.A.C. of 0.02 p.p.m. for TDI. Although it sounds highly scientific, this very low level was arrived at very simply by observations of its effect on human beings and the limits of testing methods. Experience has shown that if the level in the working environment is maintained below this, sensitization is infrequent in previously unaffected men, but men who have been sensitized may be affected even at this low atmospheric concentration. There is also a possibility of some permanent impairment of lung function in those who have been sensitized. For these reasons medical supervision of those who work or who have worked with these compounds is still required, however carefully the environment is controlled.

Byssinosis

Byssinosis is a respiratory disease which may affect people employed in the preliminary stages of the processing of cotton, usually in the cardroom and usually after they have been at the work for some years. It is characterized by a peculiar tightness or heaviness in the chest at first on Mondays some hours after starting work and later on other days of the week. Although bronchitis and emphysema may supervene in the later stages when the disease may become crippling, there are no physical signs in the early stages and the radiographic appearances are normal. It is therefore important to recognize the disease in the early stages so that affected workpeople may be removed from exposure to the cotton dust before their health is permanently affected.

The exact mechanism of the disease has been obscure but Massoud and Taylor (1964) have suggested that it is probably an immunological reaction against an antigen present in the cotton plant. They have found antibody in human sera which is directed against an antigen present in the plant. Although this antibody is found in the general population the amount is higher in cotton workers, especially cardroom workers, and it is highest of all in sufferers from the disease. Massoud and Taylor's research is now being directed towards identifying the antigen chemically as a preliminary to the next step which is to endeavour to develop a specific immunological test for the early diagnosis of byssinosis (Taylor, 1966). Meantime diagnosis still depends on the traditional resources of medicine—careful history taking, physical examination, and radiographs to exclude other lung disease.

Farmer's Lung

Farmer's lung is another occupational disease which, in its early stages, does not have any specific clinical features which serve to distinguish it from a number of other respiratory diseases such as bronchitis or asthma. In 1962 Pepys, Riddell, Citron and Clayton established that mouldy hay contains fungal antigens against which precipitins are present in the serum of patients with the disease. A specific immunological test was developed which must have facilitated the prescription in 1965 of farmer's lung in the United Kingdom for benefit under the National Insurance (Industrial Injuries) Act. The test has a high degree of accuracy and is a useful aid to diagnosis but it is no more than that; once again the diagnosis and assessment depend on history taking, clinical examination, and the other skills of clinical medicine.

Electronics

In occupational medicine the application of physical and engineering principles and technique to routine environmental studies and research is now taken for granted. Some of the new technologies have taken us into realms our art alone could never have enabled us to penetrate. To take only two examples, the science of electronics has supplied us with the means to investigate electric shock and the effect of noise on hearing in industry.

Electric Shock Recent work on the mechanism of death from electric shock is an example of the application of physics and electronics to research and practice in industrial medicine and cardiology. Some 130 people die every year in England and Wales from electric shock and about 40 of these deaths occur in industry. Until recently it had been assumed that death was caused by respiratory arrest and therefore that the correct emergency treatment was artificial respiration. Lee has shown by epidemiological studies (1965) and animal experiments (1964), which entail elaborate electronic techniques, that the commonest cause of death in electric shock is circulatory arrest due to ventricular fibrillation. This brings us right back to the individual. It means that restoration and maintenance of the circulation, and not artificial respiration, is the only treatment with any prospect of success. Closed-chest cardiac massage is therefore the recommended first-aid treatment.

It has also been shown in animals that an electric shock will cause ventricular fibrillation only if the current passes during the relative refractory period of the cardiac cycle (the T wave). If the current can

be disconnected sufficiently rapidly, the risk of ventricular fibrillation may be reduced greatly. Certain protective devices, earth leakage circuit breakers (Dalziel, 1960, 1963), have been devised to reduce the risk of death from electric shock. They act with sufficient rapidity to disconnect the current before ventricular fibrillation occurs. The development of these devices has derived from electrical science, but they have been made possible because medical science has shown how fatal electrical currents act on the heart.

Noise-induced Hearing Loss It is well known that excessive noise causes some degree of hearing loss which may be temporary or permanent and which is related to the duration, intensity, and frequency of the noise exposure. The intensity and frequency of noise can be measured instrumentally. The degree of hearing loss at different frequencies can be assessed by audiometric instruments, but this procedure is very time-consuming for large industrial populations, and the results give little reliable indication of the degree of actual disability suffered by those with partial deafness. Atherley, Lord, and Power (1966) have recently devised an electronic instrument which puts the audiometric readings straight on to punched tape in a form which can be put directly into a computer. This will facilitate and expedite studies on large groups of the working population.

The complicated electronics of noise technology, audiometry, and the computer are beyond anyone except the specialist. But we have to relate the information we get from them to the human being, whose ears are functioning organs and not electronic receiving sets, who measures his own partial deafness by the social, psychological, or working disability it may produce. We have to come back to the other end of the spectrum from advanced electronic research; we have to think in terms of its application to human beings. Atherley and Noble (1966) are therefore currently conducting research into the social and psychological effects of partial hearing loss and into ways of assessing the loss of faculty, and not merely the degree of hearing loss, of workers whose hearing has been damaged by their occupation.

Human Values

Research on many aspects of occupational medicine is being pursued by universities, government bodies, and private organizations. The Medical Research Council has units working on a large number of projects of occupational interest such as pneumoconiosis, industrial carcinogens,

body temperature, toxicology, industrial injuries, burns, railway accidents, noise, and bronchitis.

It is relevant to my theme that, despite the strong scientific content of research work and despite the need for research workers to be objective, the M.R.C. is concerned with human values and with the importance and the dignity of the individual. The Council's recent statement (1964) on the responsibility of those who conduct investigations on human subjects is a welcome reminder of the rights of the individual and of the necessity for the recognition of human values in any research which involves people, whether they be patients, volunteers or controls. The Council urges that the highest ethical scrutiny and self-discipline be exercised by those who carry out such investigations so that avoidable harm is not caused, and to ensure that the confidence of the public in those who carry out investigations on human subjects is maintained. This statement from the Medical Research Council is a timely reminder to all doctors, including those who practise occupational medicine, of our duty to treat patients and workmen as human beings and not merely as material for investigations or experimentation.

We must not lose our sense of human values to the cold exactitudes of science. While we acknowledge the contribution of the scientist to industrial medicine, we, as doctors, must think primarily in terms of human beings and human values, but we must use the resources of science to accomplish our aims. We must not think of our fellow men solely in terms of instrumentation, test-tubes, animal experiments or statistics. We measure only that which we can measure and we must beware that too great importance may be given to the results.

I have tried to exemplify how we need the doctor, trained in the art of medicine, to determine what is a departure from the normal standards of physical and mental health and to establish the biological limits to which the occupational hygienist or health physicist can work. There is as yet no alternative to the physician for supervising men exposed to many toxicological and dust hazards and for deciding in the light of the clinical and laboratory findings what action is to be taken. In the man with partial hearing loss (which we can record) due to noise (which we can measure) the loss of function has to be assessed, but we hardly yet understand and certainly cannot compute his loss of social faculty. The byssinotic and the farmer with farmer's lung present problems for the doctor and workman not just of immunological tests or of assessment for disablement pension but of diagnosis and of having to leave a skilled job or face early disablement. The

lead worker, despite the fact that his environment can be controlled by good industrial hygiene, needs medical supervision because the biological readings and other measurements do not always reflect the risk of acute poisoning from the existing situation or the possible cumulative or long-term effects. The many problems of the new concept of first-aid treatment for the man apparently dead from electric shock and the attendant dangers of closed-chest cardiac massage are problems to which medical skill and knowledge are requisite. Those exposed to dust in mines and other situations, and to asbestos and other dangerous dusts, have to be supervised until such time as we can be sure there is no risk. Routine radiographs and, more recently, lung function tests have proved useful in detecting early respiratory disease, but they need careful study and skilled interpretation.

We still need, as much as we ever needed, the good doctor in industry to apply and translate the resources of science into terms of the human workman. One of the arts of medicine is in using it for the good of the individual and the group. Hubble (1966) observes that the capacity to drive steeds so different as medical science and clinical medicine in double harness is commonplace today. Our hospitals, universities, and our Society of Occupational Medicine contain plenty of young people who are both medical scientists and good clinicians and who have in addition to these qualities a vocation to help their fellow men. They are the good industrial doctors.

If I have failed to answer the question posed in the title, I hope I have shown how difficult it is to find the answer. There may be a clue in the relative values contained in science and in medicine. Bronowski (1964) wrote that the practice of science compels its practitioner to form a set of values fundamental to the laws of the universe. Among the values which are not necessary to the practice of science (although many scientists have them in abundance) are tenderness, kindness, and sympathy. My thesis and my answer to the query I have posed are that these are the values necessary to the practice of medicine and that it is the essential art of medicine to integrate with science compassion and a love of mankind.

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