

# SCIENCE AND HUMAN WELFARE<sup>1</sup>

## I

### BIOLOGY AND MEDICINE

**M**Y SUBJECT this afternoon is "Biology and Medicine," but I think a more accurate wording would be "Medicine and Other Phases of Biology," for to my mind Medicine is a branch of Biology. Webster's Dictionary defines medicine as the science and art dealing with the prevention, cure, or alleviation of disease. Biology is the science of life. Disease might well be defined as life out of balance, and is in a strict sense a biological process. Whether it be an attack by microorganisms, or improper functioning of glands, or congenital misformation or maladjustment, or injury by poison or bullets, disease processes are in the last analysis nothing more than cells, tissues, or organs that have suffered injury and so not only fail to perform their normal functions but in most cases interfere with the normal functions of other parts, more often than not of the entire body.

Of the two great divisions of medicine dealing respectively with treatment and with prevention, the former is much the older. It is far easier to observe the effects of treatment on a person suffering from a malady than it is to understand why someone else escaped it. Some knowledge of curative or alleviative medicine was possessed by our cave-dwelling ancestors; in fact, it is instinctive in many lower animals. It gradually grew up as a sort of folklore from a slow process

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## 164 Science and Human Welfare

of trial and error, added to the instinctive knowledge acquired from pre-human ancestors.

With the growth of belief in the supernatural, by which man satisfied his developing desire to explain things, medicine became largely theological. Priests and physicians were one. They conceived disease as the work of devils, gods, or spirits which had to be appeased by sacrifices, confused or circumvented by charms or incantations, evicted by emetics, cathartics, or blood-letting, or enticed to escape by means of holes in the skull, nasty medicine, or other devices. It is since the days of our Pilgrim Fathers that we have learned that it is more effective to control typhoid and cholera by boiling water than by boiling witches.

Although belief in the instrumentality of demons and witches in causing disease persisted for a long time, since Hippocrates more enlightened individuals have recognized at least some kinds of disease as natural processes. From that time to the present medicine has been primarily biological instead of theological or metaphysical. Some of the original ideas were, as would be expected, very far astray; for example, the theory that Hippocrates inaugurated and Galen expanded that proper proportions and relations of four humors of the body were responsible for health or disease. According to this theory people were sanguine, phlegmatic, choleric, or melancholic in temperament depending upon which of the four humors predominated. Erroneous as it was, this theory was a long step forward in that it focussed attention on natural instead of supernatural causes, and on caring for the patient instead of appeasing devils.

Hippocrates was also an exponent of the great biological principle that nature is the greatest physician of all. Left alone, an organism attempts to repair damage to its parts, to adjust itself to any unbalance in structure or function

that has been entailed, and to fight off attacks by parasites. The rôle of the physician is to aid the organism in these attempts. In many cases this involves nothing more than augmentation or speeding up of natural biological processes that the organism itself would employ, such as stimulation of immunity, supply of additional antibodies, provision of new tissue or fluid in the form of grafts or blood transfusions, supply of abundant vitamins, regulation of hormones, removal of unhealthy tissue, and protection against invasion by micro-organisms. In some cases it involves methods which are entirely foreign to the natural processes of the animal body, but which aid and abet these processes, such as the use of stimulants, anaesthetics, specific drugs, X-rays, radium, or heat.

The speeding up of natural processes of repair or adaptation is applied biology. It involves a thorough knowledge of the normal biology of the human body—its anatomy and all phases of its physiology. Strangely enough, even knowledge of the gross anatomy of the human body was extremely sketchy and mostly wrong up to the middle of the sixteenth century.

Galen, of the second century A.D., was the father of anatomy for years, but he was a very poor father and his offspring was a very hodgepodge anatomy, arrived at from observations on the inner workings of monkeys, pigs, dogs, and cattle. For over a thousand years man was supposed to have a segmented breastbone like a monkey, a liver divided into as many lobes as a pig's, a uterus with two horns like a dog's, a hipbone flared like that of an ox, and a heart with pores between the right and left ventricles. If in the meantime any errors were discovered in Galen's descriptions the fault was always thought to be either with the patient or with the later observer. When Vesalius, in the sixteenth

## 166 Science and Human Welfare

century, showed that man's hipbones certainly were *not* flared as Galen described them, it was thought that they had undergone a change in the intervening centuries due to the habit of wearing tight trousers.

The study of anatomy was retarded greatly by religious and civic taboos on dissection of human bodies, but Vesalius spirited skeletons from beneath gallows and was not above occasional clandestine disinterments. He made important contributions to human anatomy, and did much to start other physicians consulting nature instead of Galen. Vesalius even reached the threshold of the discovery of the circulation of the blood, but this great milestone in the history of medicine was planted by Harvey in the seventeenth century. Probably no other single physiological discovery has had such profound consequences. What a superlative age that was, to produce a Harvey, a Shakespeare, and a Galileo!

In the eighteenth century advances were more rapid. It was in that century that another great Englishman, John Hunter, discovered that if arteries are tied off the blood will find and develop new channels. Prior to that discovery aneurisms, which were distressingly common, were treated, if at all, by amputation of limbs. John Hunter also learned some of the tricks of grafting skin and bones.

In the next century, the nineteenth, two other fundamental biological principles—the cellular structure of bodies, and evolution—came to light. Both of these ideas contribute so much to our knowledge of the human body and how it works that a full evaluation of their significance in medicine would be almost impossible.

Even with all these advances in anatomy and physiology, nobody up to the middle of the seventeenth century had any good idea what disease was or whence it came. An important forward step was made in 1687 when two Italian scientists,

Bonomo and Cestoni, showed that scabies was a disease caused by tiny mites burrowing and reproducing in the skin, and was spread by transmission of the mites. This was the first demonstration of a specific cause for a disease, and the first explanation of its spread, and was a clean break from the divine, humoral, or other ancient theories of the spontaneous origin of disease.

A few pioneering minds, a century or two ahead of their times, propounded theories of contagion, and spread of disease by dissemination of poisonous particles or gases, or even invisible living organisms, but there was no experimental evidence, and these precocious ideas fell on barren ground. A true understanding of infectious disease had to wait for the discovery of micro-organisms and some knowledge of their nature.

Leeuwenhoek, a Dutch lens grinder of the seventeenth century, who invented a compound microscope capable of bringing bacteria within the range of visibility, is sometimes called the father of bacteriology, but I think he might more properly be called its midwife. He was one of the greatest explorers of all time. Magellan and Columbus are credited with discovering continents, but Leeuwenhoek opened the door to an entire new world. Wherever he looked—in soil, water, food, excretions, or decaying materials—he discovered a host of micro-organisms that nobody had ever seen before or even suspected of existing. Modern explorers with electron microscopes are having a great time too, but their discoveries of molecules and viruses and of the minute anatomy of bacteria is hardly to be compared with the new world that Leeuwenhoek found under his microscope.

But I do not think that knowledge of the existence of insects makes an entomologist, or knowledge of the existence of stars an astronomer, so I hesitate to consider Leeuwenhoek

## 168 Science and Human Welfare

the father of bacteriology. That honor, I think, should go to Pasteur who, within the lifetime of my parents, made bacteriology a science. He did it by providing final proof that germs, like all other forms of life, require parents, and come only from pre-existing germs. As long as it was thought that germs developed spontaneously from decomposing materials the bacteriologist was in as hopeless a position scientifically as a mathematician would be if the sum of two and two varied with the weather.

From the standpoint of the control and prevention of disease this was undoubtedly the most momentous discovery ever made by man, for it alone provided a solid foundation for practically all our public health work. On it rests all our theory and practice concerning contagion and infection, quarantine, sterilization, antiseptics, aseptic surgery, purification of water, pasteurization of milk, and almost everything else on which modern practices of public health and hygiene are based. Pasteur is rightly revered for his great contribution in proving the germ theory of disease, but this would have been of little value or significance without the final abolition of the idea of spontaneous generation, which for a long time extended even to maggots and mice.

Pasteur's fundamental discoveries led almost at once to practical applications. Lister in London was quick to apply them to surgery, and by very generous application of carbolic acid to himself, the patient, the bedclothes, the air, and even the floor he brought about a very considerable reduction in the mortality from operations, which had previously been about 45 per cent even in his expert hands.

During the eighteenth century Europe suffered from great epidemics of childbed fever—at one time it got so bad that in Lombardy it was said that for a year not one woman lived after bearing a child. Europe's lying-in hospitals for

destitute mothers were humane in spirit only, in reality they were death traps. Oliver Wendell Holmes proclaimed child-birth fever an infectious disease, carried from patient to patient by physicians and midwives. Many physicians were incensed at the imputation that their hands were not clean, and Holmes's ideas didn't make much headway. It was Semmelweis of Vienna who finally dealt the death blow to childbed fever as an epidemic occurrence, and proved that even an eminent gentleman's hands are not always clean. It is within the memory of many in this audience that aseptic surgery finally supplanted Lister's heroic antiseptic measures, and that surgeons began paying more attention to washing their hands before an operation than after it.

Some twenty years after Pasteur's demonstrations of the germ cause of disease and the final putting to rest of the theory of spontaneous generation, Robert Koch developed technical methods that made possible the easy isolation and study of particular kinds of germs, and then discovery followed discovery with almost incredible rapidity. In the short space of fifteen or twenty years the causes of the majority of infectious diseases of man and animals were isolated and studied. The elusive and rather mysterious agents of disease that we call viruses, however, had to wait much longer for biologists and chemists to pry into their private affairs, and it is only now that very much progress is being made.

An infectious disease is, however, an extremely complicated phenomenon. The interaction of a parasite and its host is not a static thing like the interaction of one chemical with another, capable of simple description, and following a well-defined course. We may be too prone to think, because we know what organism causes a disease, and something about its biology, that we understand the disease it causes. Nothing could be further from the truth. We are dealing with the

## 170 Science and Human Welfare

interaction of two organisms both of which are capable of an amazing degree of adaptation to changing conditions. Every change or adaptation in one entails further adaptations in the other. A disease may be compared with an organism—it is born, it grows, it adapts itself to environment, and it finally dies. During its life it is influenced by a host of environmental factors which may profoundly alter its course.

An infectious disease depends on the presence of a specific invading organism, but this may be only one of the necessary requisites. In almost every epidemic the number of healthy carriers—people who temporarily acquire a colony of the germs but show no evidence of disease—far exceeds the number of cases. In an epidemic of cerebrospinal meningitis healthy carriers of the organism that we say causes it may outnumber the clinical cases 20 to 1. In most epidemics of such diseases as diphtheria, whooping cough, dysentery, and even cholera, the ratio is from 5 or 10 to 1.

If disease develops in only one-fifth to one-twentieth of the people reached by a particular pathogenic germ, it is evident that there are other factors playing very important rôles in its production. Among these are a proper balance of the glands of internal secretion, good nutrition, especially with respect to vitamins, and the development of specific immunity or resistance. There can be no doubt that these same factors play a large part in determining the course and outcome of a disease after it has gotten a start. A physician, then, if he is to make the most of his effort to help in suppressing disease, must be far more than a dispenser of medicine. He must, indeed, be familiar with more phases of biology than are most biologists. He must understand anatomy, histology, general physiology, endocrinology, embryology, psychology, nutrition, immunology, and even genetics in



order to have a proper understanding of his patient, and he must be a bacteriologist or parasitologist to understand the capabilities and vulnerabilities of the invading organism.

Some relations of heredity and genetics to disease have been known for a long time, but more progress has been made in genetic control of disease in plants and even in domestic animals than in man. Effects of genetic constitution of human beings on the course of disease and development of resistance are still very little understood, and still less is known about effects of genetic constitution of pathogenic organisms and means of altering it. Herein lies an almost untouched field with vast possibilities for the future.

Experimental breeding of mice has resulted in decreasing mortality from a particular disease from 82 to 24 per cent in six generations, and to 8 per cent over a period of years. In six generations of chickens mortality from fowl typhoid decreased from 85 to 10 per cent. Recent studies indicate that alterations in genetic constitution comparable to mutations in insects and plants occur also in bacteria and even in viruses. In a period of a few hours many kinds of bacteria and viruses may reproduce in such numbers that if their rate of mutation is comparable with that thought true for fruit-flies, each gene the bacteria possesses should mutate at least once. With even slightly favorable selection, replacement of the parent population by mutants is possible in short periods of time.

Viruses have many characteristics of genes, differing principally in their ability to move from cell to cell. There is evidence that the mutation of viruses is comparable with mutation of genes. The development of relatively non-pathogenic varieties of viruses or bacteria is the real basis for the production of effective vaccines against such diseases as small-pox and yellow fever, and probably for the rise and fall of

## 172 Science and Human Welfare

epidemics of cholera and diphtheria. It has recently been discovered that the virus of infantile paralysis genetically altered by mouse-adaptation, when mixed with the parent virus, has great power to protect monkeys from paralysis. What causes the protection is not yet known, but the results of this basic discovery may be very far-reaching.

Concomitant with development of knowledge of causes of infectious diseases, immunology was beginning to make its contributions to the cure and prevention of disease. You are all familiar with Jenner's discovery in 1798 of the protective value of cowpox inoculation against smallpox. As the result of that there is probably no one in this audience with a pock-marked face, whereas in Jenner's day certainly one in four of you would have been so marked if indeed you were alive at all. Jenner, however, had no notion of how his method worked; he merely observed that it did, and risked the ridicule of the medical world by saying so, and the life of his own son by testing it.

Many decades later Pasteur, making the most of an accidental observation, laid a foundation for modern immunology by showing that agents of disease can be attenuated by various means to a point where they are no longer capable of producing serious disease, but still possess the power of stimulating immunity comparable with that produced by recovery from a real attack. Just as bacteriology opened the gates to knowledge of the causes and means of transmission of infectious diseases, so the birth of immunology opened the way to knowledge of nature's principal means of combatting them.

The contributions of immunology to the cure and prevention of disease are so numerous that I can mention but a few. As aids in diagnosis I may mention the tuberculin test for tuberculosis in cattle and man; the Schick test for suscepti-

bility to diphtheria; the Dick test for susceptibility to scarlet fever; the scratch test for allergies to pollens, foods, or other substances; the agglutination tests for typhoid, dysentery, cholera, typhus, and many other diseases; the Wasserman, Kahn and other tests for syphilis; the typing tests for the pneumococci of lobar pneumonia; and many others that are less well known but no less useful when needed.

As therapeutic aids I may mention antitoxins for diphtheria, tetanus, scarlet fever, and a number of other diseases, which have made deaths from some of these diseases under ordinary conditions nothing short of criminal negligence; the helpful injections of typed pneumococcus serum in pneumonia; the use of immune or convalescent serum in cerebrospinal meningitis, anthrax, measles, and most recently influenza; and the life-saving properties of anti-venin for snake bites.

As preventive aids I need only call your attention to the wonderful records achieved by the use of vaccines against typhoid, paratyphoid, diphtheria, and more recently yellow fever. This once dreaded disease is now looked upon by the U. S. Public Health Service as of less consequence than the relatively mild and tolerated dengue fever, merely because our government has a bank of a million protective doses of vaccine which it can release if ever a case occurs within our borders. In recent years success has also been attained in production of vaccines against typhus fever and spotted fever, the former of which has hitherto been the scourge of every great war. In the present war man-made implements of destruction are more deadly than ever before, but there is no question but that this added deadliness is more than compensated for by protection from diseases, which, up to the time of the Spanish-American war, always wrought more havoc than the enemy. Such diseases as typhoid, dysentery,

## 174      Science and Human Welfare

typhus, tetanus, and yellow fever have been shorn of their power by protective vaccinations.

Closely related to the field of immunology is blood typing, which has placed blood transfusion on a safe and sound footing, and made it as routine a procedure as anesthesia or surgical asepsis. In spite of the accomplishments in the field of immunology in recent years, I think we may confidently look forward to ever greater things in the years to come. Within the past twelve months success has been attained for the first time in the artificial production of antibodies in laboratory flasks. This may open the door to future developments which may surpass anything we have yet been able to hope for.

I wish now to turn your attention to another field of biology that has contributed enormously to medicine—the science of endocrinology. No sorcerer or magician of old ever dreamed of accomplishing the miracles that can be performed today by the application of knowledge in this field. Osler, speaking of the effect of thyroid extracts on those horribly misshapen, doltish creatures known as cretins, says, “Not the magic wand of Prospero or the brave kiss of the daughter of Hippocrates ever effected such a change as that which we are now enabled to make in these unfortunate victims, doomed heretofore to live in helpless imbecility—an unmistakable affliction to their parents and their relatives.”

The science of endocrinology was born of primitive beliefs in organ magic. When our remote ancestors began to indulge in the art of thinking and had reached the stage at which they could weave together a number of scattered observations and come out with a general idea, it was a natural deduction that the kind of food you ate was a big factor in determining what sort of person you were. Tigers were thought to be fierce because they ate raw meat; it was overlooked

that a tiger fed on lettuce and carrots would undoubtedly be fiercer still, and that a meat-eater *had* to be fierce to get his meat whereas a vegetarian could afford to be timid and fleet-footed. Such thoughts, travelling along a single track, eventually reached the conclusion that courage could be acquired from eating the hearts of courageous animals or men, intelligence from eating brains, and so on. The psychological effects undoubtedly provided ample circumstantial evidence for the truth of the assumptions.

Modern endocrinology began in 1889 when a famous French scientist, Brown-Sequard, claimed remarkable rejuvenating effects in himself from injection of gland extracts. His results, too, were probably psychological, but his prestige was such that his claims started a development in medicine that has had more profound significance than any since Pasteur's discoveries of the bacterial origin of disease.

The human body is a highly automatic, self-regulating mechanism. Nature's primitive means of regulation of the body of an organism is by chemical substances secreted by its tissues. Superimposed on this, later in evolution, is an involuntary nervous system, useful in making rapid and temporary adjustments that become necessary for a body with ever-increasing activities and more and more complicated relations to its environment. Still later in evolution Nature added a voluntary nervous system but very wisely refrained from giving it control over the internal regulation of the body. As Dr. Cannon remarks, we should be greatly bothered if in addition to attending to the business of other people we had to attend to our own. The internal affairs of the body are too important to be subject to a well-meaning but neglectful and incompetent intelligence, which would as likely as not be concerning itself with the flight of a golf ball when it ought to be attending to the rate of the heart beat.

## 176 Science and Human Welfare

The chemical method is still the fundamental means of regulation of the body. Chemicals produced by tissues, which we call hormones, control such functions as growth, development, metabolism, and reproduction, and adapt the body gradually to climatic fluctuations, variations in activity, nutritional changes, pregnancy, lactation, etc. The human body is one of the most thoroughly integrated and communitistic organizations imaginable, every part sharing, according to need, with every other part, and each part influencing every other part. It is a prevalent view today that every tissue and organ in the body produces hormones or hormone-like substances that help in the integration of the entire organism. As bodies became more complex during the course of evolution, however, and the regulation more difficult, a number of special glands for production of particularly potent hormones were developed. These are what constitute the endocrine system. Some of the glands are completely separate organs having no other functions, such as the thyroid, pituitary, and adrenals. Others have developed as special tissues in already existing organs, as in the pancreas, liver, and sex glands.

The potency of these glands is almost incredible. They very largely determine what we are and how we behave. They dominate our physical stature, our mental development, our emotional status, our reproductive activity, the rate at which we live, and our ability to make use of our food. They are the architects of our bodies and the moulders of our character. A puppy deprived of its anterior pituitary gland may be converted from an aggressive, pugnacious creature to a whimpering coward, and may be returned to its former state by pituitary injections. Injections of prolactin into rats with no trace of maternal instincts will fill them so full of mother-love that they will even mother baby

squabs instead of eating them. One is led to interesting speculation as to whether injections of prolactin might not be a good alternative to execution for despotic dictators.

The hormones produced by the endocrine glands, some stimulating and some inhibitory, not only affect the body as a whole in many complex ways, but they interact with each other in such an intricate manner that we are still very far from ideal utilization of them, and we may look forward to a great extension in the future. Yet even now, only fifty years from the birth of the science, the use of hormones has revolutionized a large part of medical practice and has given new insight into many physiological processes, such as metabolic rate, sugar metabolism, blood pressure, menstrual disorders, psychotic maladjustments, adiposity, sexual aberrations, and reproductive difficulties.

Now let us turn to another contribution of biology to medicine—knowledge of nutrition. For lack of time I will pass briefly over many interesting discoveries connected with metabolism of proteins, fats, and sugars, utilization of minerals, etc., though in passing I must pause long enough to mention a relatively new tool in physiological research—the use of ions tagged by means of atoms of unusual weight or made radioactive in cyclotrons. By this means it has been found that molecules in the body, even those supposed to be relatively stable in bones, teeth, or fat, are forever being shifted about and replaced by new ones. The body is even less stable than it was thought to be.

The most significant discoveries in nutrition, ranking close to the discovery of hormones in their importance to human welfare, were those of the vitamins. Since the days of leopard skin dinner jackets and struggles with cave bears instead of dictators, man's ways of life have undergone many changes and so have his foods. With the development of

## 178      Science and Human Welfare

agriculture and civilization his food became less varied and more highly manipulated. He began to live more extensively on grain, to store food for periods of famine, and to cook it. Later he began throwing away the vitamin-bearing parts of his cereals, developed a taste for refined sugar, protected himself from sunlight, and often lived for months without fresh fruits or vegetables. Beriberi, scurvy, rickets, pellagra, and night blindness attacked whole populations.

Except for the cure of scurvy by eating lemon juice or hemlock leaves some two hundred years ago, nothing definite was known about these nutritional deficiency diseases until Eijkmann began experimenting with diseased fowls in Java forty-five years ago. Gradually during the last thirty years a whole alphabet of vitamins has been discovered, but it is only within the last decade that they have been obtained in chemically pure form, and synthesized. Few people even today realize the importance of this. Although this country is probably the best fed in the world, I do not believe it is an exaggeration to say that 50 and possibly 75 per cent of the American people do not have optimum amounts of all the vitamins they should have. They do not have scurvy or beriberi or rickets, but they have a host of minor illnesses or troubles that they need not have. Some British authorities have gone so far as to say that 99 per cent of so-called common illnesses are directly or indirectly due to vitamin deficiencies. Allowing 100 per cent expansion for enthusiasm, the figure is still impressive.

The common effects of vitamin deficiencies are such things as night blindness, susceptibility to colds, unhealthy teeth, poor appetite, gloominess, nervousness, and a tendency to fly into tantrums. An abundance of vitamins leads not only to a state of super-health in people who have always considered themselves reasonably healthy, but it is of great help



in recovery from acute or chronic diseases, repair of wounds, and resistance to infection. Even yet, many medical men tend to look upon synthetic vitamins as medicine rather than supplementary food, but gradually this is changing, and it is encouraging to see more and more foods fortified by added synthetic vitamins. Because of this and the more even distribution of vitamin-bearing foods by rationing, the general level of nutrition in England, in spite of several years of war, is better than it has ever been before. It is becoming more and more so in this country too.

The definition of Medicine includes the prevention of disease as well as its cure and alleviation. Some attempts at preventive medicine were made when disease was supposed to be caused by demons, for it was a natural inference that if the demons could be ejected they might also be prevented from entering. With the development of the humoral theories, preventive medicine was almost completely forgotten, since no one had even guessed as to how the humors could be kept in order before they got out of balance. Prevention of disease is a phase of ecology, and involves knowledge of normal bodies and their relation to their environment, including climate, atmosphere, and geological formations, as well as relations to such fellow creatures as rats, mosquitoes, lice, hookworms, amebae, and bacteria, to say nothing of viruses.

It is only in very recent times that anything whatever has been known about this phase of medicine. Only in a few instances have the processes of trial and error that led to curative and alleviative procedures led to practices that prevent disease. One of the first great triumphs in curative medicine was the discovery, in 1640, of the value of extracts of cinchona bark as a cure for malaria, but it was not until the end of the nineteenth century that a basis for the prevention of malaria was discovered.

## 180 Science and Human Welfare

A few practices of primitive people suggest attempts, probably unwitting, to prevent disease. In India, for instance, I found a primitive tribe, the Santals, who never drink water directly from a stream or pond, but from a little hole in the sand a foot or so away, thus practicing sand filtration, one of the prime tools of modern sanitary engineering. The unfitness of natural water for drinking was recognized long ago. Cyrus of Persia carried boiled water for his troops twenty-five hundred years ago. The low repute of water as a beverage even in the unenlightened middle ages is evidenced by a thirteenth-century writer who, describing the extreme poverty of Franciscan monks who settled in London in 1224, exclaimed, "I have seen the brothers drink ale so sour that some would have preferred to drink water." The head-hunting, carrion-eating Nagas of the Assam hills drink only a rice beer, carrying starters with them when they go on trips.

Preventive medicine as practiced at present has three principal legs to rest on—(1) the upkeep of natural resistance by general hygienic measures, including a proper hormone balance and optimum nutrition; (2) the artificial stimulation of specific immunity or resistance; and (3) protection against access of disease germs via water, food, air, or insect transmission.

The general principles involved in the first of these have been known for a long time, but the details have only recently been filled in by the discoveries with respect to hormones, minerals, and vitamins that I have already mentioned. I have already called your attention to the fact that in an epidemic only a small percentage of the individuals that are actually exposed develop a disease. The determining factors are the dosage of germs that gain access to an individual, and the natural resistance he has. The higher the

natural resistance, the greater the dosage he can withstand.

The second leg on which preventive medicine rests, artificial stimulation of immunity, I have already discussed. On it we depend very largely for our protection against smallpox, diphtheria, tetanus, rabies, yellow fever, spotted fever, typhoid fever, and many other diseases.

The third leg on which preventive medicine rests—protection against dissemination of germs—I have so far said little about, but here enormous strides have been made within a short space of time.

Famous in sanitary history is the case of the Broad Street pump in London in 1854, around which centered an explosive outbreak of cholera. After everything from the chemical nature of the soil to dust bins in cellars had been investigated, the relationship between drinking water from the well and attacks of cholera became clear. Nature had provided a grim lesson out of which grew modern sanitary engineering. In the intervening ninety years modern water purification and sanitary sewage disposal have developed. Whereas in 1900 the American death rate from typhoid was 36 per 100,000, today it is about 1 per 100,000, and in 1942 more than half of our large cities had not a single typhoid death.

Milk and food sanitation are even more recent developments. Even twenty-five years ago a child ran the risk of acquiring disease every time he drank a glass of milk; today the greater part of the milk supply in almost every city is pasteurized, and many cities can boast of having no raw milk.

Just fifty years ago two American workers, Smith and Kilbourne, laid the foundation stone for medical entomology when they demonstrated the transmission of a disease—Texas fever of cattle—by means of a tick. Five years after that the mosquito transmission of malaria was proved and then, at the turn of the century, came the brilliant work of

## 182 Science and Human Welfare

an American Army Commission in Havana, proving the transmission of yellow fever by mosquitoes.

Today medical entomology plays a large part in our lives. By control of insects, ticks, or mites we are able to control, in some cases almost to exterminate, many important diseases, including some of the *most* important. I need only mention the prevention of malaria, yellow fever, and dengue by mosquito control, of epidemic typhus and relapsing fever by delousing methods, of plague and endemic typhus by control of rats and fleas, and of dysentery by fly eradication.

Already we have become so accustomed to the benefits from all these protective devices that we take them for granted. Only when circumstances interfere with their practice, as is often the case in war, do we realize how much we depend on them. It was dysentery, not the Turks, that defeated the British at Gallipoli, and it was dysentery and malaria, not the Japs, that defeated our own troops at Bataan.

As we go on into the future, preventive medicine will play a larger and larger part in our lives. Instead of being a secondary and relatively unimportant part in the curriculum of our medical schools, I predict that we shall have many schools devoted primarily if not exclusively to this fast-growing branch of medical science, which is still so young that it is seldom allowed to stand on its own feet. The subjects taught will be very largely biological ones, such as medical entomology, helminthology, protozoology, bacteriology, immunology, the newly-developed field of aerobiology, and methods of sterilization and disinfection which are also a branch of biology, since they deal with the destruction of life.

In addition to the categories of discoveries in biology that I have already mentioned, there are other fields of biological research which are making valuable contributions to both preventive and therapeutic medicine. I have time only to

mention in passing a few of the discoveries made in the year 1942.

During the past year great advances have been made in the long-neglected field of aerobiology, dealing with the distribution of pollens, fungus spores, micro-organisms, etc., through the air; new knowledge of the spread of contagion through the air has been obtained, and new methods of control worked out, using vapors and ultra-violet rays. Also within the year there have been a number of new biological methods of controlling pathogenic organisms, including discovery of an enzyme-like substance in young rats, by which tuberculosis bacilli may be shorn of the waxy coats that protect them from drugs and phagocytes, and discovery of germ-killing substances extracted from molds and from various types of soil bacteria. In the field of nutrition, evidence for the need of particular amino-acids for special functions in the body have been demonstrated, and may pave the way for better control of these functions in the future. New methods have been developed for the study of the ultimate connections between nerves and muscles, which may lead to better control of paralysis and muscular diseases. Announcement has also been made of the development of germ syrups, at negligible cost, which change the bacterial life of the human intestine so that, like deer and cattle, we can not only digest the cellulose of grass, leaves, and wood, but can also synthesize our own supply of B vitamins within our own bodies. In research on cancer, which is one biological problem that is still unsolved, a number of significant advances have been made. A few more pieces have been fitted into the mosaic, bringing the final picture a little nearer to completion. In this field as in that of allergies, there is still much to be done, but there is every reason to believe that it *will* be done before very long.

## 184      Science and Human Welfare

In all these biological accomplishments, we have had to depend to a very large extent on experiments on animals. Few of the great discoveries in physiology, immunology, endocrinology, vitaminology, treatment of infectious disease, anesthesia, surgical procedures, or cancer research could have been made without the help of guinea pigs, dogs, rats, monkeys, or other experimental laboratory animals. Just as brave young men are sacrificed on the field of battle to save us from slavery and degradation, so helpless animals are sacrificed to save us from the bondage of disease. Although we deliberately expose our brothers and sons to destruction for the greater good of our country, we do it with the deepest regret for the suffering they may have to endure, and we make every effort to minimize that suffering. So it is with the biologist and his experimental animals. Contrary to the imaginings of those well-meaning but misguided persons who call themselves anti-vivisectionists, biologists do not enjoy seeing animals suffer; they in fact suffer with them, and relieve them of pain or unnecessary suffering whenever possible. Some biologists may be sadists, but I have yet to meet one.

None but the biologists themselves, and the medical men who profit from their results, can fully appreciate how much, how *very* much, the comfort and safety of the human race depends on the experiments for which their experimental animals have suffered and died. It is difficult not to suspect the reflection of a suppressed sadism in the accuser when one hears experimental biologists referred to as heartless, cruel, or hateful. It should not be forgotten that God sacrificed his only begotten Son that man might live; it is difficult to believe that He would disapprove the sacrificing of laboratory animals that man might have a greater share of health, happiness, and security.

Man's ingenuity has freed him from many phases of the struggle for existence to which other creatures are subject. He has gained an insuperable advantage over the wild beasts, and his inventive genius defies the attacks of climate and the elements. In his struggle against disease he has, as we have seen, made wonderful progress, although he still has far to go. There is some reason to hope that after the present global war has burned itself out we may be able to free ourselves from the one phase of the struggle for existence that man's ingenuity has steadily made more terrible, the struggle of man against man. With all the phases of the struggle for existence well in hand we may then turn to a struggle for improvement of our kind by the application of two other branches of biological science, genetics and eugenics. Within our own generation preventive medicine has grown out of therapeutic medicine; perhaps our children may live to see a still newer branch of "improvement medicine," in which endocrinology, nutritional studies, problems of aging and rejuvenescence, and eugenics will lead to greater health, more happiness, longer life, and better evolutionary prospects than have hitherto been our lot.

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