# Science as Human Evolution

by

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# FOREWORD

This book, which was written on a long sea voyage from New York to Sydney at the end of 1962, represents essentially six years of my thought since writing my small introduction to science "The World of Nature". The quiet of a month at sea provides an ideal environment in which to set down ones conclusions on the fundamental problems of Mankind, to which problems too many people give far too little thought today. Man is now in such an advanced stage of his evolutionary development in which it is possible for him to understand the significance of life for him, not as a matter of religious belief, but as the opportunity to use his inherent abilities to work towards a world transcending in its perfection any of which he could have dreamed before the advent of science. I have here written about Man's biological, social, and scientific advances in order to show that science is essentially the most recent phase of human evolution, and that it is entirely conceivable for us to choose to base our world civilization solely on reasoned, objectively provable, thought: that is, science. The arguments for the fundamental conclusion of the necessity to accept a scientific philosophy, which I have called individualism, are given in full, and the way in which to achieve the practical realization of a scientifically ordered world is discussed. It is my hope that, after their careful reading of this book, my readers will appreciate that the scientific world view offers us the only rationally acceptable way to solve the great problems of our century.

*S. Archer.*
Pacific Ocean, December, 1962.

# Contents

# Science as Human Evolution

# I

In writing this book it is my aim to attempt an analysis of the position in which Man, as the highest product of evolution on the Earth, finds himself at the present time. This position has been reached as the result of a long biological evolution traceable to pre-human ancestors at least 600,000 years in the past; a social and cultural evolution extending back to more than 20,000 years ago; and a comparatively short but very significant scientific evolution beginning some 300 years ago effectively. The facts concerning Man's activities within the past few thousand years are recorded in written history, and much evidence bearing on Man's earlier development is available from the scientific study of archeological remains found in many parts of the world. With the evidence before us, and providing that we are willing to objectively consider its real significance for Man's future progress, I believe that we can discern a path to take which will enable us to obtain those great benefits of full individual lives in a peaceful world for which men have hoped for centuries.

It certainly is worthy of our serious thought to consider the possibility of our attaining a world society in which all human beings could be free of food deficiencies, in which the best medical care would be available to all for the virtual elimination of disease, and in which each individual would have the opportunity to develop his or her abilities to their fullest and would be rewarded for doing this. However we must, from the outset, recognize several fundamental difficulties which have slowed Man's advance in the past and are still continuing to do so. These hindrances are, I consider, firstly, the tendency to hold to many beliefs unfounded on objective evidence; secondly, the assumption that individuals are justified in making others carry out their own wishes, whether by the direct or indirect use of force; and thirdly, the view that the individual owes to society more than what he has mutually agreed to exchange with other individuals for their work.

Under the first heading must be included all forms of mysticism and pseudo-science, and all forms of religious faith, for none of these beliefs can be substantiated in a way which can convince all people of their correctness—indeed the existence of so many conflicting tenets in the various religions of Man, which have not been resolved for thousands of years, surely indicates strongly the basic falseness of religion in its world view. Under the second heading we must note that this assumption is at the root of all large scale human conflicts, and that it is the cause of enormous misery for men throughout the ages, for if men had not accepted the right of the individual to impress his wishes on others, none of the dictatorial civilizations would have been possible. Under the third heading must be placed the origination of societies in which the primary significance of individual thought and action has been replaced by the action of groups—leading to the slowing down of Man's evolution and the eventual decay of the socialized societies concerned.

In contradistinction to the foregoing difficulties scientific method provides us with clear solutions of the major world problems facing us today; the basic assumptions of science are open to objective test by all who wish to do so; present scientific knowledge indicates that the manner in which research is conducted gives the best likelihood of success possible to us in tackling any given problem; available knowledge shows that the Earth can be altered to support many more people in completely satisfactory conditions than existing at present; and unbiased examination of our losses to be experienced in giving up subjective beliefs, particularly religion, show that these would not be serious.

I think that intelligent men and women should today make an effort to take stock of our position as a still evolving species, an evolution which would appear now to be essentially one of increasing knowledge of the material universe and an ever more superior ability to change our environment to suit our needs, and to contemplate our future into the unknown millenia ahead and what we hope to work towards in that future. I can feel confidence only in the reasoned solution of our problems, in which we apply our own abilities in scientific method, as our guide to help us to attain that future world which we can, even with present knowledge, certainly reach. The universal adoption of a scientifically based international policy is entirely conceivable to us, since the fundamental conclusions of science are accepted by essentially all who have studied them (this includes scientists, engineers, medical men, and many laymen also), and the rapid growth of scientific education is now providing a steadily increasing percentage of the world population with the means of rational thought for themselves.

Indeed, present trends in higher education in both the United States and the U.S.S.R., which are the two most important nations, clearly indicate that well before the end of this century the scientifically trained individuals will considerably outnumber the individuals trained in all other disciplines. This situation will lead to the scientists exercising a predominant role in international affairs, and to their greatly strengthened collaboration in the development of pure science and in the application of science for practical needs, so that all national governments will find themselves obliged to concur in facilitating the plans of the scientists, since if such governments do not aid their scientists as they are asked to do, they will lose the support of their own people who will be ever more anxious to follow the reason of science in matters concerning them.

It should also be observed by all governments that, since the conduct of any future wars is dependent largely on the supply of new types of weapons devised by scientists, it is within the power of the scientists to halt the creation of further weapons and possibly even to divert present war materials from being used for war puposes. It is also quite probable that before the present century closes the scientists will insist on even the internal government of each country being conducted largely by scientists, and there is little doubt that they will require the formation of a world government of scientists before that time. The members of such a world government would be elected by the governments of individual countries, and would be the most able scientists in the world.

The alternatives to a world-wide adoption of scientific government appear today to be as follows: A world, nominally “free”, based on the individual-nullifying democracy of the United States; a world, essentially of slaves, based on the communism of the U.S.S.R.; a world, in effective chaos, based on the communist methods of China; and a world, in which reason would be extinguished, based on the tenets of some major religion, e.g. catholicism. Let us hope that we shall choose the way of science instead, that way which is in reality the latest phase in Man’s evolution.

## II

In order to gain knowledge regarding the probable future evolutionary development of the human species, we may consider the evolution of some pre-human species which have lived on the Earth, or the descendants of which continue to live on the Earth. The vertebrate line of animals, of which Man is a product, may be traced to the early armoured fish (ostracoderms) which first appeared in the seas in the Ordovician period which started 500 million years ago. There followed the sea-scorpions in the Silurian period starting 440 million years ago, and then the ancestors of modern fish (with scales) in the Devonian period starting 400 million years ago. Early amphibious animals appeared at the end of the Devonian, and continued to develop into the Carboniferous period which began 350 million years ago. During this period reptiles became the first animals to breed on land, and they rose to terrestrial dominance in the succeeding Permian period starting 270 million years ago. In the next geological period, the Triassic, beginning 225 million years ago, the first mammals evolved from the reptiles, but these forerunners of Man remained small throughout the next two periods (the Jurassic, starting 180 million years ago, and the Cretaceous, starting 135 million years ago) in comparison with the dinosaurs which ruled the land until their extinction during the mountain building activity starting at the end of the Cretaceous period. By this time the placental mammals with their protected young had developed, and these evolved into numerous types of modern mammals, including the ancestors of the horse, pig, and cattle during the Eocene period starting 70 million years ago. During this period primitive monkeys also first appeared, which gave rise in the next period — the Oligocene, starting 40 million years ago — to a primitive tail-less ape living contemporaneously with the ancestors of modern dogs, cats and bears. In the succeeding Miocene period, which began 25 million years ago, the primitive anthropoid ape called Proconsul, which lived in central Africa, migrated into Asia and Europe, and the number of man-like ape species increased on into the Pliocene period (beginning 11 million years ago) while the number of other mammalian species declined — possibly because of the changed climatic conditions over the Earth, which became more varied during the Miocene period. Finally, in the most recent Pleistocene period starting 1 million years ago, ape-like animals developed intelligence enabling them to make stone tools as weapons and for use in handling killed animals. These marked the transition to primitive man, who probably originated in Africa and lived in forest and open country. He spread outwards to Asia and Europe and was able to thrive and evolve his intelligence and manual skills through the cold periods of the Ice Age and the warm interglacial periods — when other mammals were forced to migrate away from the glaciated regions in Europe, America, and India, or were rendered extinct by the hostile climate. With the coming of the end of the last period of ice, about 12,000 years ago, Man learned how to domesticate certain animals and to cultivate certain plants for food and other purposes. These advances in his evolution made possible the growth of large human communities, which afforded men opportunities to specialize in many different occupations in which they made many discoveries of new ways in which to control their environment. The resulting increased effectiveness of material production led to men having time for thought about their world, which gave rise to science based on experiment.

Although Man is clearly a still evolving species, and we cannot of course predict with certainty to what new species he will give rise in future millenia, we can examine the nature of the long-term evolutionary changes undergone by earlier types of animals. Some well studied animal evolutionary lines are those of the dinosaurs, the elephants, the fish, the horse, and to some extent the apes leading to man.

The dinosaurs evolved from a group of reptiles known as theriodonts, which lived in the Triassic period, the theridonts having evolved from the cotylosaurs (Permian), the cotylosaurs from the labyrinthodonts (Carboniferous), and the labyrinthodonts from the choanicthyes (Devonian). The choanicthyes were primitive armoured fishes, while the labyrinthodonts were amphibious reptiles; the latter became extinct in the Triassic period, but their primitive reptilian cotylosaurian descendants gave rise to the more advanced reptilian theriodonts before this happened. The cotylosaurs themselves experienced extinction at the end of the Permian period, while the theriodonts suffered the same fate late in the Triassic period. However the theriodonts had given rise to the dinosaurs before their extinction, the first dinosaurs being only about six inches long. But these reptiles continued to evolve into ever greater sizes, attaining lengths of over 80 feet in some species, through the Jurassic and into the Cretaceous periods, where the whole group became extinct. Thus an evolutionary line, lasting some 130 million years from the appearance of animals smaller than a foot in size to the final extinction of the great dinosaurs over one hundred times as large, was eliminated by the changing environment in which major mountain-building activity took place. The previously swampy river deltas in which the giant dinosaurs lived were thus submerged as the coastal land sank along the edges of the newly rising mountain ranges, which included the Rocky Mountains, the Andes, and many European ranges. The dinosaurs had in fact become so specialized to suit their environment that they were unable to survive in different conditions.

The evolutionary line of the elephants, which still continues today although the number of these animals is diminishing rapidly as man alters their natural environment, began in the Eocene period (about 70 million years ago) as the primitive mammals of the Cretaceous gave rise to many modern types. By the time of the following Oligocene period there had evolved small elephants with short trunks and tusks in both jaws, and during the Miocene these produced ever larger elephants which spread from Africa to Europe, Asia, and America. In the Pliocene period elephants continued to thrive, and in the succeeding Pleistocene considerably larger elephants appeared. However the Ice Age occurring in this last period caused several elephant types, e.g. the woolly mammoths, to die out. These huge creatures were cut off from escape to the south by the advance of the glaciers and snow in Siberia, and in fact completely preserved specimens have been found buried in the ice. It thus appears that the elephant line would have a duration exceeding some 70 million years if its environment had not been radically altered, since these animals are well adapted to their normal jungle habitats. But, as in the case of the dinosaurs, the elephants have become rather specialized to adjust to their environment, which thus limits them to rather small regions now as the world's jungles are being cut down by man. It appears unlikely that these great vegetarians will be able to survive much longer in the present world.

Morern fish are the descendants of animals originating from new Silurian vertebrates in the Devonian seas approximately 400 million years ago. Some of the primitive sharks attained a size of 20 feet. In the succeeding geological periods the fishes were present in many different types in all the seas, and although they were dominated by larger carnivorous aquatic reptiles (ichthyosaurs in the Triassic-Cretaceous, and mososaurs in the Cretaceous periods), they were able on the whole to escape predation. This was due to their great agility in the water aided by their "lateral-line" sensory system which detects disturbances in their surroundings, and to their great breeding abilities. During the Cretaceous period new types of fish closely related to the present-day porbeagle sharks, rays, and herrings evolved, and with the extinction of marine reptiles by the time of the Eocene most fish species resembled the types existing today. However further varieties of fish appeared in the Miocene, including very large sharks over 60 feet long. The latter died out in the Pliocene, while the other fish species changed very little on to the present time. In the fish we see therefore a line of animals, lasting at least 400 million years, in which a fairly standard pattern has resulted in practically perfect adaptation to the liquid environment. Since the overall conditions in the seas do not change appreciably even during Ice Ages there is every likelihood that fish will continue to populate the waters for a long time yet. But their severe limitation of being confined to breathing water-dissolved oxygen means that the fish are unlikely ever to evolve any organs of intelligence which would require a more efficient means of energy release than the fish possess.

The horses alive today form what is perhaps the most completely studied animal group as regards their evolution. The ancestors of the horses first appeared in the Eocene period, some 50 million years ago. The diminutive Eohippus, about as large as a spaniel dog, possessed four toes on each front foot, and three on each hind one, and lived in the newly appearing grasslands bordering the forests of this warm climate. As the climate cooled in some regions in the following Oligocene period, causing an increase in grasslands and dwindling forests, the larger Mesohippus and Merychippus (Miocene) species evolved, the number of toes diminishing to three on all feet, and the structure of the biting surfaces of the teeth increasing in complexity to give better grass-chewing ability. With their lengthened legs and gregarious habit, these horses were enabled to elude their feline predators, and as the new Alps (Oligocene)) and Himalayas (Miocene) rose and divided Europe and Asia into varied climatic zones the horses migrated into new regions. The new great grass plains of North America were invaded by horses crossing the Bering Strait during one of its periods of elevation as a land bridge between Asia and America. In the Pliocene still larger horses (Pliohippus) with only one toe on each foot had evolved, while later in the Pleistocene horses (Equus) as we presently know them appeared. These had only the single hoof which provides such excellent strength to the very long legs of the horse — permitting this animal the very high and sustained running speed which it has today. The jaw was now greatly deepened and lengthened for powerful chewing, and considerable intelligence in the horse's brain, together with acute hearing and smell, resulted in almost perfect adaptation to the grassland habitat. Given a continuation of extensive grasslands, the horses would therefore appear to be capable of continued existence well beyond their present 50 million years of evolution. But unfortunately, as for the elephants, man is altering the horse's natural environment to permit more extensive agriculture. Unless some important use for horses is found, (and their use is steadily diminishing now with the improvement of powered machinery), it therefore seems that these fine animals are doomed to extinction in perhaps a few centuries only.

Now we may consider the evolution of man himself, the essential course of which is traceable through the many discoveries of prehuman remains in several continents, especially in recent years. To ourselves this study is probably the most interesting, but it will repay us to approach it in a strictly unbiased attitude if we wish to deduce its true nature. Man is a very recent development of the mammalian line, and in fact is not as anatomically evolved as some other mammals, e.g. the elephant and horse. Our five-digit limbs are primitive, as also is our short face with small jaws. But our brain size, especially in the pre-frontal lobes, is greater than that of any other of the higher animals, and our excellent eyesight and manual dexterity have given us the ability to perform operations far more complex than those performed by other animals.

The earliest creatures, which may be ancestral to modern man, known today, are the Australopithecinae of South and East Africa, remains of which have been found in gravels at Sterkfontein, Makapan and Swartkrans in South Africa, and at Olduvai Gorge in Tanganyika. These finds date from about 600,000 to 400,000 years ago, the period between the Lower and Middle Pleistocene. The Australopithecines possessed many human features including limbs, teeth and upright posture, but their stature and brains were small compared with those of present-day men. Approximately contemporaneous with these ape-like men there were living the Pithecanthropi of Java and China, and the earliest Neanderthal men in Europe. Remains of Pithecanthropus have been found at Trinil (Java) dated about 350,000 years ago, and at Peking (China) of age about 400,000 years. The Pithecanthropi had a bigger brain and other more advanced features than the Australopithecines, and they made tools and used them. The earliest Neanderthal man known is Heidelberg man (Germany) of which only the jaw has been found: its age is about 400,000 years. The Neanderthalers developed into two types (Middle Pleistocene) known as "primitive" and "progressive", the latter approaching modern man more closely. At Swanscombe (England) remains of a man possibly ancestral to modern man and the more recent Neanderthalers, of age about 200,000 years, were discovered, while another discovery at Steinheim (Germany) was of a "progressive" type of Neanderthal man dating perhaps 50,000 years later than the Swanscombe man.

By the end of the Middle Pleistocene (100,000 years ago) there were thus several types of man in existence, deriving from the Australopithecines, Peking and Heidelberg man, although the main line of the Australopithecines had disappeared somewhat earlier, and Peking man does not appear to have influenced the later evolution of man in Europe. Modern man (Homo Sapiens) thus seems to have arisen from the mixing of Neanderthal types, and indeed at Mount Carmel (Near East) skeletons of both Homo

Neanderthalensis and Homo Sapiens have been found, together with intermediate physical types. Evidently at this time we see the division into the two new spceies of men.

The Neanderthalers were cave-dwellers during the last glaciation, and were widely spread in Europe, Asia and Africa. They had receding foreheads, with a brain capacity equal to that of modern man. They are undoubtedly very important in the evolution of modern man, who may have originated when West European and West Asiatic Neanderthalers came together. Many Neanderthal remains have today been discovered at different sites: e.g. Neanderthal (Germany), Gibraltar, Le Moustier (France), Shanidar and Mount Carmel (Near East); and a related type at Saldanha (South Africa). However about 20,000 years ago the Neanderthalers became extinct in competition with Homo Sapiens, modern man evidently using his greater mental abilities to outwit the Neanderthal man. From this time onwards human remains have been unearthed at many places: At Cro-Magnon (France) lived tall, fine-boned men with large brains bringing the new Aurignacian stone culture probably from Asia, about 20,000 years ago; at Cheddar Gorge (England), 10,000 years ago; at Boskop (South Africa), 15,000 years ago. About 15,000 years ago the three basic groups of present-day man — Caucasoid, Mongoloid, and Negroid — had started to differentiate, and some Mongoloids crossed via the Bering Strait into America, and a few early Caucasoids moved down the East Indian island chain into Australia. Traces of man in America appear at Tepexpan (Mexico), Punin (Peru), and Palli Aike (Argentina); these people developed into the American Indians in their geographical isolation from Eurasia. In Australia evidence of man appears at Keilor (South Australia) — the Australian aborigines developed in isolation as Archaic White people, and were still in the Stone Age when they were discovered in the seventeenth century.

Some 7,000 years ago began the Neolithic Cultures which started agriculture and the domestication of animals. These peoples lived in larger groups than early man had done, and built wood dwellings (e.g. the lake dwellings of Central Europe). Their social groups were able to resist attack by more primitive men, and made possible the beginning of various new activities including the extraction and use of copper, the use of clay to make vessels for food and water, and the development of early wooden ships. Around 3000 B.C. Neolithic men migrated from the Eastern Mediterranean into the British Isles and other parts of Europe. A people — the Megalith Builders — came by sea to Britain, where they constructed the stone monuments such as Stonehenge — a very difficult feat for people with only primitive mechanical devices. These structures were orientated with reference to various astronomical bodies, and served the purpose of determining the time of year (important to agriculture), besides being used as tombs for the dead and as places of worship of the accepted gods. Another people, called the Swine Culture from their keeping of pigs, travelled by land from North Africa, crossed the Gibraltar Straits, and went on into Italy, Switzerland, Germany, and East Britain. And, around 2000 B.C., a third people, known as the Bell Beaker Culture from their characteristic drinking vessels, migrated from Eastern Spain into France, Germany, and Britain. These people had the newly invented bronz — a copper-tin alloy — much superior in its properties to copper: this metal thus replaced stone in the making of weapons, leading to the Bronz Age.

From about 2500 B.C. the first large civilizations arose in the Near and Far East, these being centered on the great river valleys of the Nile in Egypt, of the Tigris-Euphrates in Iraq (Mesopotamia), and of the Yellow River in China. Smaller, but later contributing to the major, civilizations arose in Europe (Crete) and India (Indus river valley). While in South America there arose the Aztecs and Incas, but these were cut off from any interaction with the remainder of humanity.

The Tigris-Euphrates civilization, with its great cities of Babylon and Ur, irrigated the river valleys, invented the first form of writing — the cuneiform on clay tablets — and devised the sexagesimal system of mathematics (it being thought at first that there were 360 days in a year, so that the circle was divided into 360 degrees). The individual cities were at first separate states (the Sumerian City States), but later united to form the Babylonian Empire. By 1700 B.C. they had an efficient system of government and law, and had discovered iron smelting. By 1100 B.C. they had conquered the Eastern Mediterranean peoples, and these Assyrians governed from a new capital at Nineveh. The Assyrian king Ashurbanipal collected the first library of 20,000 tablets, about 700 B.C. In 600 B.C. the prophet Zoroaster taught a religion based on a God of Light — this was adopted by Cyrus, who founded the Persian Empire extending from the Indus to the Nile, but this empire was destroyed in 320 B.C. by the Greek, Alexander the Great.

The Egyptian civilization, one of the greatest the world has ever known, produced the earliest large buildings of precise geometric shape — the Pyramids at Gizeh. This required a considerable advance in trigonometry — this branch of mathematics developed with the need to mark out lands annually after the Nile had flooded. The Egyptians were irrigating the Nile valley, and using the Solar Year, prior to 2,000 B.C. during the "Old Kingdom" of Egypt. The Pyramids were essentially tombs for the kings, and the effort put into their construction reached a considerable portion of the total national effort at its highest. The dead were embalmed to preserve them, on the assumption that they might attain another life after physical death — an assumption basic to many religions. In the period of the Egyptian "Middle Kingdom" (starting about 2,000 B.C.), the form of picture writing called hieroglyphics, written on papyrus reed, was invented. This made possible a record of historical events and trade transactions. Architecture was further developed in the "New Kingdom" (beginning about 1600 B.C.), leading to the erection of the Temples at Thebes. And although the Egyptians were conquered by the militarily superior Assyrians about 900 B.C., architecture, science and medicine continued to flourish and were later advanced still further by the Greeks.

The great civilization of China, the oldest of the living civilizations, began before 2000 B.C. with the "Sage Kings" who developed agriculture, river use, and medicine. About 1800 B.C. the ancient Chinese had formed a lunar calendar — used until the present century — and had begun to record their history in their complicated system of characters — an idealized form of picture writing. During the period of the Shang Dynasty (c. 1700 B.C. to c. 1000 B.C.), the original Yellow River peoples spread to the north and south, and first made silk and used bronz in making vessels. In the next period, the Chou Dynasty (c. 1000 B.C. to c. 400 B.C.), the Chinese rule reached to the Yangtze River, and irrigation works were constucted.

Fine artistic works of bronz and semi-precious stones, were produced, as also was some great poetry. But lack of a strong central government resulted in disturbances at times. The basic present-day philosophies of China arose in the sixth century B.C. with the teachings of two very wise men, Lao Tse (590 B.C.) and Confucius (550 B.C.). In this Golden Age of Chinese philosophy these men set forth certain beliefs and principles of behavior which accorded well with the already prevailing tenets of ancestor worship held by the Chinese. Lao Tse advocated a somewhat mystical passive belief in the harmony of nature, which does not encourage much advance. But Confucius, whose descendants living today can trace their line back for over seventy generations (the longest known human descent), advanced a more active manner of living. In essence, Confucius taught that the intelligent man should always behave wisely according to his knowledge, implying a strict moral code. This idea is a forerunner of a philosophy based on scientific knowledge known to ourselves today. However, Confucianism does not significantly encourage the increase of knowledge, in contradistinction with modern science.

In the succeeding Ch'in Dynasty (c. 400 B.C. to c. 100 B.C.) a strong central government replaced the weak Chou government, and the Great Wall of China was built to halt repeated northern invaders This construction, approximately 2000 miles long, about 20 feet wide, and 15 feet high, is the largest man-made object on the Earth, although the Panama Canal required a greater excavation of material than is contained in the Great Wall. The next period of Chinese history, the Han Dynasty (c. 100 B.C. to c. 300 A.D.) saw the foundation of institutions for the education of the upper classes, and the initiation of the first permanent Civil Service (the Mandarins) for the administration of government. The civil servants were appointed by competitive examination — a procedure which is surprisingly not employed in the selection of members of modern governments. During the Han Dynasty, the religion of Buddhism was introduced into China from India, and paper was first used.

From about 300 A.D. for three centuries China underwent a period of disorder — the Dark Ages — caused by continued invasions of the aggessive Huns and Tartars from the north, but with the start of the Tang Dynasty (about 600 A.D.), followed by the Sung Dynasty (c. 900 A.D., a further period of central control united the Chinese in a Golden Age of culture. Science, art, and learning flourished: the magnetic compass, printing from blocks, and gunpowder were first devised; beautiful porcelain was manufactured, and painting was advanced; and contact with other countries (India and Arabia) was effected. But about 1250 A.D. China was conquered by the fierce Mongols led by Ghengis Khan, and became part of the Mongol Empire. Kublai Khan however encouraged foreign contact (e.g. Marco Polo from Italy) and trade, but did not succeed in conquering Japan or Indonesia. The Mongol rule was cut short about 1370 by the Mings who revived the Mandarins and Confucianism; also art and learning. Jesuit missionaries from Europe visited China about 1600 and reported on the great scientific and cultural heights attained by the Chinese. The Ming Dynasty was replaced by the Manchus (c. 1700) who included Korea, Mongolia and Indo-China in their territory. The Manchus were anxious to keep foreigners out of China, but from 1850 onwards several European nations traded with the Chinese. The failure of an anti-European rebellion in 1900, and the formation of the Chinese Republic in 1912, ended

Imperial China. The most recent phase in Chinese history, which has until very recently remained largely independent of the history of the European nations, was the imposition of Communist government on China in 1949. However, in view of the declared antagonism of this government to the traditional Chinese philosophies, it does not appear likely that it will be able to control the country for long. But the new Chinese government has started the country on important large-scale programmes in the mechanization of agriculture, the improvement of industry, and especially extensive education including the advance of scientific research.

The earliest Indian civilization was established by the Dravidians in the Indus Valley some time prior to 2000 B.C. These people possessed irrigation schemes, developed pottery, and had a good governmental system. They also carried out trade with the Mesopotamians. In the seventeenth to thirteenth centuries B.C. they were invaded by Aryan peoples from the northwest, who settled in India and mixed with the Dravidians. The Hindu civilization thus arose, based on Hinduism — the belief in the continuous existence of each mind, which through repeated reappearance in successive animals (including man) could eventually attain to immortality as the highest being called Brahma. Although there is no real evidence of the rebirth of any mind known to us today, it is interesting to note that the Hindu religion did state that this salvation was to be accomplished through knowledge, in agreement with what we might accept with our modern scientific knowledge. However, the result of the social division of the Hindus into hereditary classes of social organizations (castes), on purely religious grounds, has produced a serious decrease in the pace of Indian evolution.

The next important event in Indian history was the founding of the much more far-reaching religion of Buddhism by Gautama Buddha about 580 B.C. This brilliant thinker concluded, after a lengthy consideration of human misery in his time, that peace for the mind ("Nirvana") could be secured by withdrawal from the world, with meditation and self-control. Buddhism aims at the removal of mental anxiety by the suppression of wishful thinking not leading to permanent happiness for the individual. Buddha also emphasized that attainment of the tranquil mind was dependent solely on the individual's own ability, and that no supernatural aid could be expected. Undoubtedly Buddha's ideas of personal meditation, self-control, and the use of personal abilities are to be upheld by modern thought, although too great an amount of withdrawal would suggest a tendency towards schizophrenia today. Under the Mauryan Dynasty (c. 300 B.C. to 0 B.C.) nearly all of India became united, and the great emperor Ashoka (280 B.C.) established Buddhism and sent missionaries to nearby countries; advanced education, hospitals, and roads; and maintained peace. But in the next two centuries this Empire was destroyed by further foreign invaders, and India remained divided into various states.

The peak of Indian achievement was reached during the Gupta Dynasty (c. 250 A.D. to c. 700 A.D.) when a unified people developed science, art, and literature. In mathematics, the decimal system with zero was used; in astronomy, great stone instruments were built, and the rotation of the Earth was theorized; in architecture, shrines and temples were erected; poetry was written; and Sanskrit was used as the literary language. At the end of this period another series of invasions, this time by Huns and Arabs, caused this Empire to disintegrate into rival Hindu kingdoms — Buddhism was vanishing from India itself now, going to Burma, Ceylon, and Thailand where it continues today. In about 1000 A.D. Muslim invaders began settling in India, and they ruled the Hindus during the following seven and a half centuries. The first Muslim Dynasty was started in c. 1200, and in about 1520 an empire was created under the Mogul Babur. The Moguls restored order in the country, and the enlightened emperor Akbar encouraged trade with other countries, promoted art and science, and tolerated all religions. The famous, beautiful, Taj Mahal monument was built at this time, which was the most brilliant in Muslim-ruled India. However, the decline of Mogul power, and rising conflict between French, Dutch, British and Portuguese traders, eventually resulted in Britain taking over the rule of India after the British victory over France in the Seven Years War. Thus from about 1750 until the independence of India and Pakistan (Hindu and Muslim respectively) was gained in 1947, India was an Empire under Britain. This period although broken in its middle by the Indian Mutiny, saw the development of much needed transport systems, a strengthening of order, and the origination of simpler currencies in India. Today India is making considerable progress in its effort to use modern scientific knowledge to solve the many problems facing the rapidly growing population.

The origin of modern Western civilization lies in the small island of Crete in the Eastern Mediterranean Sea, where from before 2000 B.C. the Aegean people achieved a remarkably advanced culture which is being studied carefully today. These people were traders with Europe and the Near East, and they developed a linear form of writing (recently deciphered) which greatly faciliated records as compared with the previous slow hieroglyphics. The Cretians used copper and bronz, and migrated to nearby Greece. Crete itself was ruined by Indo-European invaders around 1400 B.C., but these people absorbed the Aegean culture and developed into a number of City States in the Greek Peninsula during the succeeding centuries. These States, Sparta, Athens, Corinth, and Thebes, provided the stimulating environment in which rapid cultural and intellectual advances were made, and new ideas could be tried out. The Greeks employed the Phoenician alphabet devised by these seafarers, founders of the great city of Carthage in North Africa (c. 790 B.C.). Among the great Greeks of this period were the poet Homer, the dramatists Aeschylus and Sophocles, the statesman Pericles, the mathematician Pythagoras, the philosophers Socrates, Plato and Aristotle, and the energetic military Alexander the Great (310 B.C.), Alexander came from the small state of Macedonia, but soon conquered all Greece. His armies, the greatest and most modernly equipped with cavalry existing in his time, were able to destroy the large Persian Empire, resulting in the further spread of Greek culture. Science and philosophy advanced rapidly in the newly founded Alexandria in Egypt, one of many new cities built. Euclid (280 B.C.) drew up the basis of geometry, and Archimedes (240 B.C.) advanced both mathematics and physics together. The Greek thinkers clearly perceived the underlying order of Nature, and made use of their scientific discoveries in practical life. But, although they speculated on the atomicity of matter (Democritus), and on the nature of life (Aristotle), studied astronomy and geography (Ptolemy, c. 130 A.D.), and gained some knowledge of the human body and the treatment of disease (Galen, c. 140 A.D.), they were hindered in their scientific approach to the solution of problems by their unwillingness to employ experiment in validating their hypotheses. The intellectual class was in fact not conducive towards any kind of manual work, owing to the use of slaves to do this. Thus modern science did not appear in civilization for another fifteen hundred years. Nevertheless we owe a great debt to the ancient Greeks as the first people on the Earth who were able to challenge the old view of the functioning of the Universe under the control of superhuman deities. The Greeks had their own gods, but those were considered to be anthropomorphic in character, and certainly the Greek thinkers felt themselves capable of free action under their own conclusions.

The Hellenistic Empire continued until about 100 B.C. when Greece was conquered by another rising people, the Romans. These people originated in the city states established by early Greeks in Italy around 800 B.C., Rome itself being founded in c. 760 B.C. The original inhabitants of Italy, the Etruscans, combined with the Greeks, and a Roman Republic was formed. The Romans succeeded in conquering Italy and held the power in the Mediterranean, and in about 270 B.C. destroyed Carthage. In the first century B.C. the Romans reached a Golden Age in architecture and literature (with the great writers Cicero, Virgil, and Livy) and the general Julius Caesar conquered France and Britain. In the next century the Greco-Roman culture was diffused into all parts of the Roman Empire, from Persia to Spain. This was made possible by the construction of a wide road system, by the establishment of an effective administrative system over the territories, and by the general recognition of the rights of the free citizen of the Roman Empire. This idea of the international acceptance of a citizen's rights was the forerunner of similar ideas holding for several major modern nations.

During the period of Roman supremacy in the Mediterranean area, an important new religious teacher appeared in the small country of Palestine, which had been occupied by the inherently religious Hebrew people since about 2000 B.C. These people, despite enslavement by the Egyptians around 1600 B.C., and later by the Babylonians (their great city Jerusalem was destroyed c. 550 B.C.), had managed to maintain their integrity for some twenty centuries because of their powerful religious convictions. In the first century A.D. Jesus Christ, whose birth was supposed by his biographers to have been parthenogenetic (probably on religious grounds), taught Christianity in his country. The basic tenet of this faith was the belief in an omnipotent God who was considered able to give immortality in an extraterrestrial domain to those of his followers implicity accepting him, and acting in accordance with the moral laws stated by Christ. These included the recognition of the rights of one's fellow-men, the service without material reward of others, and the discarding of prejudices against other peoples of different descent from one's own. Although Christ's conclusions regarding the tolerance of all men are to be upheld wholeheartedly today, his advocation of the service of men to others (with the hope of an eventual heavenly reward of life after physical death), do not receive support in the light of our present knowledge of Man's evolutionary development. And the whole concept of the continued existence of the mind apart from the body is open to very serious doubt to us today. To Christ during his life, which was cut short by his execution by the Romans, were attributed various miraculous actions, but these are probably explicable in terms of his strong psychological personality. (a similar strength of personality was possessed by Gautama Buddha). Particularly interesting are the records by Christ's immediate followers of his apparent physical reappearance after death: if these are correct, then it would seem that this phenomenon might indicate a new, but very rare, property of man. However it appears to be better at present to explain this event in terms of a purely psychological projection taking place in the minds of those reporting it. Nevertheless these people were convinced of the reality of human resurrection, and they actively advanced Christianity in the Roman Empire, succeeding in acquiring the recognition of the Emperor. Unfortunately the absolute acceptance of this religion by the majority of the European intellectuals for centuries afterwards made it impossible to undertake any open-minded enquiries into Nature, the Church adopting the view that essentially all had been solved by the Greeks. Consequently European civilization underwent a Dark Age (the Medieval period from c. 500 A.D. to c. 1300 A.D.), when earlier acquired knowledge was merely handed on to succeeding generations. However a few men, notably Francis Bacon (c. 1620), saw the necessity of testing scientific theories by actual experiment, and that an advance in real knowledge of Nature would make possible a better control over natural forces by Man to meet his own needs. It was not until Bacon's suggestions were made, however, that men attempted to carry out appreciable experimental work.

The next great civilization to appear after the time of Christ was that of the Arabs. These people were inspired by the great religious teacher Muhammed (c. 640 A.D.) who declared the existence of a single God, and that he himself was a prophet. Despite the intense religion which this man thus originated, his ideas were more primitive than those of Buddha and Christ in the intolerance of other religions which he advocated. This in fact led to the Muhammedans undertaking bitter wars against surrouning peoples, and by c. 1500 they had conquered all North Africa, the Near East, and Spain, and had reached Vienna. However from this time their influence declined with their unsuccessful attempts at world domination. But nevertheless civilization profited on the whole from Muslim activity, for during their period of supremacy lived men who upheld the scientific investigations of the Greeks and indeed advanced them. Among these men were the philosopher and great doctor Avicenna (c. 1030 A.D.); the explorer Batuta (c. 1350 A.D.); and the writer Averroes, who produced commentaries on the works of Plato and Aristotle. Mathematics was considerably advanced by the Arabs, who used the Indian numeral system and invented algebra. Astronomy, geography, and alchemy all flourished in Arab civilization (the ideas of paper and block printing were obtained from China), although the then predominant aims of alchemy—the discovery of a method of converting metals into gold, and the search for a chemical cure for all diseases, were fruitless. The alchemists learned a great deal about simple chemical reactions however, which formed the basis of the new science of chemistry later on. The idea of chemicals for the treatment of disease was nevertheless a sound one, and thus the Arab alchemists may be credited as the founders of chemotherapy. The great Arab cities were at Damascus (Syria), Baghdad (Iraq) and Cordova (Spain).

Around 1050 A.D. the Arab Empire was taken over by the fighting Turks from Central Asia, who stopped trade between Europe and the Far East, and ruled the conquered countries by military power. This Ottoman Empire lasted until 1800 when revolts in the Balkan countries caused it to break down. Today Turkey remains alone as a Republic.

Japan began as a region inhabited by a seafaring people coming from the Pacific islands in about 400 B.C. The early Japanese developed largely in isolation until the fifth century A.D., when contact with China led to Buddhism being accepted alongside the primitive Japanese religion, and to the use of the Chinese character system of writing. The Japanese excelled in art and landscape gardening in the fourteenth to sixteenth centuries, but the feudal character of their social structure made further advance in acquiring knowledge practically impossible. Although Japan resisted European attempts at communication, the country was forced to open to trade in c. 1850 by the United States of America. The Japanese thenceforth developed into a great industrial power, discarding many of their former superstitions. In 1941 they attempted to gain territory in the Pacific from America, to improve their population position in their overcrowded island, but the Japanese War was an eventual complete failure. Since 1945 Japan has regained a leading position in world trade, but the Japanese must still look towards nearby lands into which to expand—particularly the Australian Continent.

The great Roman Empire of A.D. 200 broke up into Eastern and Western parts around 260 A.D. with the rise in Christianity. The Church, with its Pope in Rome, came into conflict with the Roman Emperor (who had accepted Christianity), since the respective spiritual and economic-military outlooks of these two leaders were essentially incompatible. From this division the present-day attitude of the Catholic Church can be traced, in particular its views regarding the control of population growth in the present world. The idea of a single empire based on Christianity, although readvocated by Charlemagne about 800 A.D., failed to carry conviction, and many of the clergy were evidently withdrawing from the world's life into the numerous monasteries founded between 300 and 1300. The Eastern Roman Empire, or Byzantine Empire, broke off from the Roman Church and spread its culture to Russia and the Balkan countries, but was later overwhelmed by the Turks (Constantinople falling c. 1440). The Byzantine civilization produced some very fine art and architecture during its height. The Medieval period in Europe is notable for the construction of fine cathedrals (in keeping with the spiritual outlook of the times), and also for the foundation of the first great universities (e.g. at Bologna, Florence, Rome, Padua, Vienna, Prague, Heidelberg, Paris, Oxford and Cambridge). The main subjects of study at these universities at first were the Greek and Latin classical literature, Christian theology, history, art, and mathematics, although later medicine was added to the curricula.

The most recent phase in Man's cultural development, the rise of experimental science, began in the fourteenth century during the period known as the Renaissance and Reformation, when what amounted to a revolution of the intellectuals against the dogmatism of the Church took place. Interest in classical knowledge, both artistic and scientific was greatly helped by the first use of the printing press about 1440 by Caxton. The slow, and not always accurate hand copying of books was thus replaced by the far more efficient printing process, although the Latin language was used by the intellectuals for centuries still. The new thinkers included such men as Luther, who caused a major division in the Church with his protests of dictatorial behavior of the Pope; the great artist Michelangelo; and the scientist-artist, Leonardo da Vinci. The latter two men lived in the wealthy trading Italian city states, where beginning in the seventeenth century men tried to solve some of the ancient problems of knowledge along the lines suggested by Bacon. The first great experimental scientist was Galileo c. 1640) who founded the science of physics, and obtained conclusive proof with his telescope of the correctness of the heliocentric theory of the planetary system advanced in the previous century by Copernicus—so displacing the Earth from its previously believed position as the centre of the Universe. In medicine the important discovery of the circulation of the blood in animals was made by Harvey (c. 1630), and in philosophy and mathematics Descartes (c. 1660) advanced an essentially scientific view and invented analytical geometry respectively. But the greatest achievement of science was produced by Newton in his researches in theoretical and experimental physics, resulting in the statement of the fundamental laws of motion, the discovery of gravity, and the first understanding of the nature of light.

In the next century came the first great application of scientific reasoning to improve Man's condition on the Earth—the construction of the steam engine by Watt (c. 1780). The great philosopher Kant (c. 1770) attempted a survey of knowledge, and first suggested that the Milky Way with the Sun and its planets might be but one star system among many in the Universe—a hypothesis validated in our own century. Chemistry was put on a sound footing by Lavoisier (c. 1780) who demonstrated the actual events happening during burning, even showing that respiration was of the same nature—an important step towards a physico-chemical theory of living matter. The generation of electricity on a useful scale, made possible by the invention of the dynamo by Faraday (c. 1830), led to the release of a new force to aid human effort unequalled in its usefulness even today. Faraday made many other significant contributions to physics and chemistry, including discoveries bearing on the structure of matter and the nature of electric and magnetic fields of action. Using Faraday's results, Maxwell (1873) postulated the existence of radio waves which were later produced experimentally by Hertz (1887). Dalton (1803) first explained the known laws of chemical combination of the elements in terms of an atomic theory, and Hutton (1785) concluded from his observations of the Earth's rock strata that our planet must be tremendously old—a conclusion confirmed by Rutherford (c. 1910) during his studies of radioactivity. Steel was made on a large scale by Bessemer about 1850—the start of our modern age of materials. And in 1859 Darwin declared his conclusions on the fundamental process of evolution of living organisms—the most important discovery ever made in the field of biology— and so greatly strengthened the position of science with a consequent weakening of the position of religion in human affairs. The actual laws of biological inheritance were discovered experimentally by Mendel in 1865, and with the microscopic observation of the detailed processes of cell division, involving the discovery of the chromosomes and genes within the cell, in the first decades of the twentieth century, Darwin's ideas received strong confirmation. The further study of electricity in the latter half of the nineteenth century led to the discovery of the free electron by Thomson (1897)—one of the fundamental particles composing all matter—and then in rapid succession the discovery of X-rays (Röntgen, 1895), and of radioactivity (Becquerel, 1896).

In this century the arts received much attention also, great work being produced in the fields of painting (Turner), literature (Goethe), and music (Beethoven, Chopin, Verdi). The basic arguments for a socialized state were put forward by Marx in about 1860. The diesel engine was invented (Diesel, 1893). Photography was successfully employed (Talbot, 1839). And medicine made huge strides forward, firstly with the proof of the germ nature of many diseases stated by Pasteur (c. 1860), and secondly with the discovery of anaesthesia by Morton (1846).

Finally, mainly in our own century mention must be made of the fundamental advances made in physics: the discoveries of the proton by Rutherford in 1911, and of the neutron by Chadwick in 1932, primary constituent particles of matter; the elucidation of the atomic structure of crystals by Bragg in 1913; the artificial transmutation of elements by Rutherford in 1919; the creation of artificially radioactive isotopes by Curie and Joliot in 1934; the Theory of Relativity, including the calculation of the energy-equivalence of matter, by Einstein in 1915; the foundation of the Quantum Theory by Planck in 1900, and Einstein's particulate explanation of radiation in the photoelectric effect (1905); Bohr's explanation of atomic structure (1913), and Rutherford's proof of the existence of the atomic nucleus (1911); the theoretical discovery of mesons by Yukawa (1935); the study of cosmic rays (Millikan, 1922). In chemistry: the complete understanding of the chemical combination of atoms (Pauling, 1939); the determination of the chemical structures and the synthesis of many biological compounds including sugars (Fischer, 1883 onwards), amino-acids (many workers, c. 1850-1935), and chlorophyll (Strell, Woodward, 1960); much progress towards a detailed knowledge of the structures of several proteins (Crick and Watson, 1953; and Perutz & Kendrew, 1960); the synthesis of polymers (long molecules). In biology: the detailed study of the genetics of several species (Morgan, 1904 onwards); the discovery of viruses (Ivanovski, 1892); the elucidation of the function of viruses (1930 onwards); the use of the electron microscope (1932 onwards). In psychology: the Theory of Psychology of Freud (c. 1910); the experiments by Pavlov on conditioned reflexes (1900 onwards); the studies of visual perception by Köhler (1929). In medicine: the elucidation of the function of the pancreas (Banting and Best, 1921); the treatment of certain cancers with radium (c. 1900 onwards); the establishment of the cause of malaria by Ross (1898); the use of antibiotics (from c. 1930); the success in performing heart operations (Rehn, 1896; the successful prevention of poliomyelitis (Salk, 1954); the discovery of electrical waves in the brain (Berger, 1929). In geology: the radioactive determination of rock ages (c. 1920—); the discovery of remains of fossil men (Breuil, 1901—; von Koenigswald, 1937; Black, 1926); the mapping of the ocean floors (Heezen & Tharp, 1961), leading to the discovery of the mid-oceanic ridges; the confirmation of Wegener's continental drift hypothesis by studies of rock magnetism (Blackett, 1960); the first descents by bathyscaphe into the ocean depths (Piccard, 1953); the discovery of the ionosphere (Appleton, 1925); concentrated studies of the Antarctic (1959). In astronomy: the theoretical understanding of stellar energy generation (Eddington, 1926), and of the dynamics of star systems (Jeans, 1919); the detailed investigation of the Sun's surface (Hale, c. 1890—, and others); the study of magnetic fields in stars (Babcock, c. 1950); the photographic determination of star distances (Schlesinger, c. 1900—, and others); the discovery of the period-luminosity relation for variable stars (Leavitt, 1912); the determination of the size of the Milky Way (Shapley, 1918); the discovery of the red shift effect of galaxies (Slipher, 1912—), and the conclusions as to the immense distances of these objects (Hubble, 1924); the discovery of radio waves from the Milky Way (Jansky, 1932), and of radio stars (Hey, 1946; Ryle, 1952); the continuous origination theory of the universe (Hoyle, 1948); the first astronomical observations from space (of the Sun, 1946). In engineering: the construction of great bridges (George Washington Bridge, 1931; Golden Gate Bridge, 1937); the building of skyscrapers (Rockefeller Centre Building, 1931—); the construction of enormous ships (Queen Elizabeth, 1938; United States, 1952); the achievement of powered flight (Wrights, 1903), and the building of huge airliners using the jet engine invented by Whittle (1930); the construction of the Panama Canal (1914); the use of hydroelectric power for the generation of electricity, with the building of great dams (Boulder, 1936; Kariba, 1958); the driving of heavy railway trains and large ships with diesel engines, and of large ships with steam turbo-electric units; the construction of great optical (Palomar, 1951) and radio (Jodrell Bank, 1957; and Cambridge, 1958) telescopes; the building of nuclear reactors (c. 1950 onwards) for energy generation and radio-isotope production; the construction of immense rockets for journeys into space, and the placing of artificial satellites in circum-terrestrial orbits (1957—); the development of long-distance radio communication (Marconi, 1911), and of television (Baird, 1930); the invention of the radio valve (de Forest, 1906) and of the transistor (Bardeen and Brattain, 1948); the construction of electronic computers (c. 1950—), and of giant "atom-smashers" for physical experiments (c. 1936—); the invention of the klystron (Varian, 1937), of the magnetron (c. 1938), and the development of radar for navigation (1940—); the invention of the ciné camera (Friese-Green, 1889) and of the tape recorder (Poulsen, 1889); the invention of the airborne magnetometer (about 1945); the invention of the hovercraft (Cockerell, c. 1953) and hydroplane (Ricochet, 1906) surface vehicles; the use of nuclear power in submarines capable of long and deep submersion, and to power surface ships.

The rate of advance of science and technology together since 1900 has indeed been very great, and is increasing continually. There seems little doubt that as men come to realize even more fully the ability of science to achieve great things, so the world will become willing to accept a basically scientific outlook for the future. The fact is simply that, from the earliest human attempts at an understanding of the world, it has been made ever more clear to man that this world, including man himself, is objectively real, and that things happen according to definite rules—called physical laws. In any given set of circumstances the same event will be repeated—that is, the same causes produce the same effect. Although parts of modern physics would deny strict cause-and-effect relations as always prevailing, one should note the extreme conceptual difficulty of rejecting the cause-and-effect hypothesis, which is basic to our present-day science, and without which Man would not have gained the control of natural forces which he has gained.

# III

Let us now consider for a while some early ideas regarding Nature and Man. No doubt even the most primitive men occasionally thought about some of the problems which they recognized during their short lives, although they did not achieve a satisfactory solution to these problems in most cases. But we have certain knowledge only of the thoughts of men back to the beginning of writing, some 5,000 years ago. However, the wall paintings, and practices of Neolithic man as revealed by buried remains, which have been studied so far by archaeologists, indicate the nature of human thought back to perhaps 20,000 years into the past. A more complete knowledge of Man's early mental activities must await further discoveries of archaeological remains.

Starting, then, with the finding of human skeletons evidently buried by Man, burial being a practice common with early men, we can conclude that these men believed that in some manner a person might continue to exist even after death had occurred. For presumably they would not have taken care to protect the bodies of the dead unless they had thought that these would be able to function again —unless burial was intended simply to honour the former living, which appears unlikely. Alternatively men may have considered that if dead humans were eaten by animals (or perhaps by other humans!), the eaters would gain additional powers which would make them worse enemies against which to fight. In view of the insistence of religions even today on the immortality of the human mind, we can feel that this idea lay at the basis of early burial practices. Man is ever hopeful of what the future may bring, so that it is quite natural that he should have concluded long ago that he might attain a better kind of life in a different world after death on the Earth. The leaders of early human groups might well use the idea of heaven to enforce moral laws on their people, making correct behavior in life a condition of passage to heaven.

Another thought of early man must have been how was the world formed? It was clear enough that the world was rather large, since these men did not reach limits to the land in even their furthest journeyings, except along the sea shores. It was also evident that the world must be a good deal older than the oldest living men, since they had no memories of the formation of the world. Man also realized that new people came from older people, and since he did not know that evolution of men occurred, he assumed that the very earliest men must have been created, along with animals, plants, and the Earth itself, by supernatural forces. In this way man could explain his lack of knowledge of the formation of things. These ideas of creation are contained in many of the major works of religion written by men in later times, when the origin of things had become even more distant in the past than was probably believed at first. It is remarkable that primitive men did not suspect any connection of Man with apes, since the apes resembled him quite closely. But this may have been due to a different geographical distribution of men and apes, the latter living in warmer climates generally than men did. so that man did not encounter terrestrial apes often.

There were several further puzzles which early human thought would have encountered, but was unable to solve. These included the causes of winds, rain, and hot and cold weather; why people sometimes became ill; and how did the Sun, Moon and stars apparently float in the sky without any supports. It seems likely that very long ago Man noticed that some events had visible causes: e.g. he obviously realized that day was bright because the Sun was shining above the world, and that night was dark because the Sun was then absent; that men had to eat in order to live; that animals could be killed if they were damaged seriously enough; that he himself must keep reasonably warm or he would die. Thus men would have simply extended the idea of causes for various happenings to include unobservable causes for certain kinds of events. Since no evident cause of wind, rain, heat, or cold was observable, these phenomena would be attributed to forces of an unknown kind, that is to supernatural forces. The same sort of explanation was advanced for disease, and the heavenly bodies were supposed to be controlled by superhumans, or gods. Thus we have the early view that many natural events were really caused by gods, and all early peoples seem to have adopted this idea. Since these gods were supposed to be a sort of superior human being, and the good favors of humans could be won by means of suitable gifts, it was assumed that the same method of obtaining the cooperation of the gods was correct. Consequently we find early men making presents for their gods, which were usually burned at places of worship at appropriate times: the flames, with their mysterious properties (not understood until modern times), would be supposed to transfer terrestrial goods to the gods' celestial abode.

Usually different phenomena were attributed to different gods, but later men thought that only a few gods would suffice to effect things, until several peoples concluded that a single deity would prove adequate. Thus we note that the ancient Egyptians and Greeks had numerous gods: the Chinese still hold this view today. But by the time of the early Hebrews, one god (Jehovah) was accepted by these people, while the Christians adopted this same view in their God: (although the Christians concluded that their founder, Christ, also possessed godlike characteristics). The Hindus had many gods, but Brahma was regarded as the actual creator of the Universe, although quite beyond the reach of human beings. Buddhists were advocated by Buddha himself to rely only on their own intelligences in attaining their ends, and he set forth those principles of successful life which he himself had discovered. But his followers later deified him against his wishes, Buddha never having claimed in life to have deific attributes; (in contrast to Christ who declared himself to possess a relation to God). Buddha still accepted the existence of Brahma as the creator of the Universe. The great Chinese philosopher Confucius was more concerned with human behavior in life than with any afterlife. But he thought the worship of ones ancestors necessary as well as conformation to moral rules, evidently because the dead were supposed to possess superhuman powers which could aid their living descendants. While Muhammed accepted but a single god (Allah), and claimed only prophetic powers for himself.

Nature is complicated in her (a deification here again, which has become a convention) phenomena, far too complex for us to understand by pure thought alone, and many great thinkers have failed essentially to do so in this way. Until the advent of experimental science gave us a means of obtaining correct answers to some of our many questions about natural events, men were thus more or less forced to assume the existence of a deity as the originator of events, if they were to maintain the cause-and-effect hypothesis. But with the ever increasing success of scientific discoveries in explaining natural phenomena, including many exhibited by living beings including ourselves, we can today quite reasonably assume that many other unsolved problems will yield to scientific study, and that we can hold our minds open on unsolved issues for which insufficient evidence is available to enable a decision to be made. We should note that it is not only in the physical sciences that a deep understanding of Nature is being reached, but also in the life sciences. We are certainly learning a great deal more about the human mind, for example, than was ever known in past centuries, and we are just beginning to understand why we behave as we do, and what factors influence our behavior. There seems no valid reason today why we should accept religion as a necessity any longer, although human irrationality may continue to compel some individuals to accept the deity hypothesis for the remainder of their lives.

Since experiment is the distinctive feature of modern science which differentiates it from other forms of knowledge, it is worthwhile to enquire what were possibly the first experiments performed by Man. These may include the making of fire, the shaping of stone for weapons, and the use of tree branches as levers.

Although fire was most likely to have been encountered naturally by primitive Man, started by lightning striking trees or by the spontaneous combustion of decaying vegetable matter, he must have sought some method of generating fire for himself when required. He would have had, at first, to have carried burning wood from a natural fire to his living ground, and to have maintained the fire by addition of wood. But rain would have extinguished his fire, and he might have accidentally let it go out sometimes. Also, it was difficult to transfer fire any great distance, so that when Man moved after the animals on which he lived, he would have had to leave his fire behind. Since fire served at least three very important purposes to early Man, viz. for warmth in cold weather, for roasting his meat, and for scaring away fierce animals, it was really essential to find a way to create fire at will. The discovery that rubbing two pieces of wood together could generate a considerable temperature was probably suggested by the similar experiment of rubbing the hands together: next the rubbed woods were shaped so that one was pointed at one end and this end could be placed in a cavity in the other, so that on rapid twisting of the first stick friction at the point raised the temperature locally rapidly, which was helped by the poor thermal conductivity of wood. A small amount of inflammable material, e.g. wood slivers, placed in the heated cavity would now ignite when the firemaker blew vigorously onto it. Thus was solved the problem of producing fire artificially, an example of a primitive experiment.

The making of shaped stones for various uses began very far in Man's past, even the earliest fossil men known today having had stone tools. Probably the simplest use for a stone to Man was as a hand-held chopper for striking animals: naturally shaped stones were no doubt found at first for this purpose, but few would have had the ideal shape of a sharp front portion with a rounded rear to fit the holding hand. However, the extreme hardness of stones made it appear at first impossible that any method of shaping them could be devised. Nevertheless some early men found a deposit of pieces of flint, washed down by a river, and noted that these stones were often broken giving flat faces. This suggested that such stones had the property of easy breakage in some directions, leading the discoverers to try shattering flints themselves. They thus found that, indeed, a flint could be shaped quite readily into a useful shape by means of judicious blows with another stone—thus the first crude (or Old Stone Age) tools were produced. Later refinements, involving the pressing off of small pieces of flint, gave the nearly perfect tools of the New Stone Age.

A more advanced type of experiment was the discovery of the use of tree branches as levers for moving heavy boulders. Perhaps several men one day, while moving along a rocky cliff face, dislodged a boulder which fell on and trapped one of their number. Despite all efforts of the individuals pushing together, they were unable to remove the rock to free their companion, so that they were desperate. Then the most intelligent man, noticing a broken-off tree branch nearby, took hold of it as a tool for a renewed attack on the boulder. The branch did not help him any more than before when he pushed the boulder with it, but then he observed the small space below the boulder and thrust the branch into this. Now he found that pushing on the free end of the branch had a much greater effect than before, and the boulder moved slightly. With a tremendous heave at his branch he dislodged the boulder to the amazement of the others. Thus this man discovered the lever, and probably he experimented further with this new kind of tool, using it to roll boulders for fun. To this day levers form essential parts of many of our machines.

In all the cases discussed in the foregoing, discovery consisted of observation of a natural situation; the need to control that situation to achieve a certain result; attempts at producing the desired result in a way suggested by the individual's thought based on his available knowledge; and the success of one of these attempts. Once success had been achieved, the method could be handed on by demonstration to other people: a new technique had been created by Man

# IV

By around 1000 A.D. it appeared that, although considerable progress had been made since the time of the early Egyptians in developing new methods of using natural materials, including several metals extracted from their ores, and glass had been made, a number of major problems seemed unanswerable with the techniques then available. Such problems were: the actual structure of the astronomical universe, including an explanation of the planetary motions ,and the nature of the stars and planets; the manner in which the surface features of the Earth and the seas were formed, and how old they were; the way in which animals and plants originated on the Earth, and the fish in the seas; how each species was able to reproduce itself; how the human body functioned internally, including what comprised thought; what was the process of combustion; what caused the winds and what caused the tides; what was the structure of matter itself, and why did it appear in the forms of solid and liquid (gases were not recognized as material); and especially, what caused disease, and how could diseases be treated successfully.

Although speculations, in many cases little more than unfounded beliefs, were available concerning these matters, these did not satisfy the more curious men of intelligence, who although generally accepting the religious dogmas of their day, were desirous to discover logical solutions to these important problems. These early thinkers did not particularly wish to find new ways in which Man might control Nature, except in the case of discovering how to conquer disease. Certainly, as century succeeded century in European countries with little change in human ways of life, men little dreamed of developing vast new powers such as science has given us in the past three centuries. But the essential property of the human mind, rational thought, made some men doubt the ideas accepted by the majority of people, since it was evident that these ideas were often irrational. The religious leaders did little to encourage any clear thinking in any sphere, since they accepted the validity of the various religious texts without question, and were largely concerned with enforcing religious rules upon the people of all classes. Some few occupied themselves in endeavors to reinterpret the books of faith, thereby giving the weight of their scholarship to the pronouncements of the preachers, sufficient to convince the most intelligent of rulers. None attempted to examine the incongruities of the various religions, those holding one religion assuming that they were correct in their beliefs, and that other people accepting different religions were incorrect. Since nobody could prove the validity of their position, a state of affairs which still holds good for every religion today, there was no possibility of deciding who, if anybody, was right and who was wrong.

During the seventeenth century, however, some intelligent men decided that it might be possible to reach some definite conclusions on the outstanding problems of knowledge by applying the experimental method of approach previously advocated by Francis Bacon. They also noted that several of the crafts and professions of their time, e.g. metal extraction, glass making, medicine, had accumulated bodies of empirical knowledge which were little known to scholars, but which might help in the solution of other problems if explanations of these empirical facts could be devised. Thus began the age of reasoned enquiry into Nature, in which enquiry the relation between academic thinker and practical craftsman has been of the greatest importance from the start. Always advances in pure scientific knowledge and in the application of new knowledge to serve Man have gone together, although the practical utilization of a new discovery has often been delayed for a decade or so after the discovery was made. But just as mankind cannot achieve any rapid advances in daily life without the unhurried original research of the pure scientist, so the latter cannot advance far in his never-ending search for new truths without the help of the practical man who can make new equipment for the scientist to use in his work. However it is most important to note that the rate of scientific advance is governed by the rate at which the leading scientists work, by the numbers of scientists doing original pure research, and by the extent to which these scientists receive financial support for their work: it has recently become apparent that some governments, for example that of the United States, are inclined to hold the view that only heavily financed researches can produce important new discoveries, ignoring the fact that practically all of the great discoveries of the past have been made by individual or small groups of scientists, often working with rather simple equipment. Furthermore, it is also necessary to point out that it is often not possible to predict in advance which scientific discoveries made at any given time will prove to be of practical importance say ten years hence, so that it is difficult for the sponsors of science (governments largely, today) to support those researches of greatest eventual economic importance. The only sensible thing to do is to give support to all lines of research, however improbable they may seem to be likely to lead to important practical results.

The first definite knowledge regarding the nature of matter, and of the energy associated with matter, came about the time of Galileo (c. 1590). Galileo investigated the manner in which objects moved when falling, overcoming the difficulty of observation of the rapid motion of freely falling bodies by allowing metal spheres to roll down a groove in an inclined plane. In this way the motion was slowed sufficiently for accurate measurement of the position of a moving sphere, at successive instants of time, to be made. Galileo devised the pendulum for measuring short time intervals, having noticed that the period of swing of a pendulum was independent of the amplitude of the swing. By using a short pendulum he was thus able to divide time into a series of equal intervals of length about half a second. These experiments showed that the rate at which a descending sphere increased its speed was exactly the same whatever the weight of the sphere, although a large sphere was of course moved by a larger force (the effective part of its weight down the inclined plane) than was a small one. Since the force of its weight acting on a body to make it accelerate did not affect the magnitude of the acceleration, it was evident that bodies must possess a property enabling them to resist the action of forces acting on them; this property is called inertia. It was simply necessary to assume that the inertia of any body was proportional to its weight to explain the observed constancy of acceleration of all bodies in the same conditions. This property of inertia is the fundamental characteristic of matter as one constituent of the Universe.

With the investigation of moving bodies it became clear that matter was associated with another entity normally — this was energy. Since a moving body did not appear to differ physically from the same body at rest, but when in motion it could produce considerable effects on being brought to rest, it was said to possess energy due to its motion, or kinetic energy. Similarly, a body located at a height above ground must possess additional energy as compared with that it has when at ground level, since on falling to ground it becomes capable of exerting a large force on the ground while it is being stopped. The body at a height is thus potentially able to produce mechanical effects, and is therefore said to have potential energy. The swinging pendulum is a very good example of a body possessing both kinetic and potential energy: at the moment of the release of the bob from a position to one side of the rest position, the pendulum has potential energy only; but as the bob accelerates in its arc of swing, the pendulum gains kinetic energy, while losing potential energy since the bob is descending towards its lowest position; when the bob has reached the lowest point in the swing, its potential energy is a minimum, but it is now moving at maximum speed and so its kinetic energy is a maximum at this moment; further motion of the bob upwards to the other end of the arc of swing results in the bob losing speed and thus kinetic energy, but gaining potential energy. It is quite easy to show, when mathematical expressions for the kinetic and potential energies of the pendulum are derived, that the maximum values of these two kinds of energy possessed by the oscillating pendulum are the same, so that the pendulum converts one kind of energy into the other continually, the total amount of energy being constant. Although many other forms of energy have been recognized since Galileo's time, (and even matter itself is now considered to be a kind of energy), this principle of the conservation of energy within any isolated system still holds true, and this is one of the fundamental laws of Nature. Energy, although essentially intangible, is concerned in all changes taking place in the Universe, and is the other fundamental constituent of the Universe; (or the only one, if matter is regarded as a kind of energy). There is, today, no definite proof of the existence of any entities other than matter and energy, but a few rare human psychological phenomena appear to suggest that something else may possibly exist.

During the centuries following the first studies of matter in motion, the concepts of matter and energy became clearer as further discoveries were made in physics and chemistry. The sixteenth and seventeenth centuries saw the experimental proof of the constancy of total mass (as measured by the weight) of substances taking part in chemical reactions — i.e. a chemical reaction involved only the formation of new substances from old, without any change in mass. Gases were realized to be also a form of matter and to have appreciable weight; owing to their very small density they had previously escaped notice to a large extent. They were found to be involved in many important chemical reactions, including the combustion of inflammable materials and in the respiration of animals. As for reactions of non-living substances, it was also shown that the total mass of a living thing changed only by an amount equal to the mass of any materials taken in or given out by the animal: in particular, respiration was proved to be a process of combustion involving the oxygen from the air, but here no high temperature was produced as in the flame. The law of the conservation of mass was thus established for living matter also, and with the development of methods of chemical analysis it was demonstrated that the living organism was composed of the same elements as were present in inorganic Nature. The energy changes going on in plants and animals were found to obey the law of energy conservation also. These facts made it seem rather probable that living systems were in fact complex physico — chemical ones, and the present-day view of most biologists is that the explanation of the function and structure of living things should be sought in terms of such a picture.

During the nineteenth century the first proof of the minute structure of matter, and very important information on the nature of light, was obtained. Dalton, in 1803, gave the first scientific description of the structure of matter when he showed that the known laws of chemical combination could be explained, quite simply, by assuming that all substances were composed of extremely small particles — the atoms. The ancient Greeks had postulated the existence of atoms to answer the question whether it would be possible to continually subdivide any piece of matter for ever, so that there would be an infinite number of pieces, or whether one would eventually arrive at pieces which could not be further subdivided. The Greeks, disliking the concept of infinity, concluded that matter was atomic in nature, but they had no proof of this conclusion. In his Atomic Theory, Dalton postulated as follows:

(a) Every chemical element is composed entirely of atoms, identical in size, mass, rigidity, etc. for any one element, but different for different elements.
(b) The atoms maintain their mass and individuality in all chemical reactions in which they take part.

(c) Chemical compounds consist of "compound atoms" (nowadays called molecules), in which the atoms of the elements forming each compound are united in fixed, whole number, ratios.

The laws of chemical combination, determined experimentally, showed that all chemical compounds were formed by the combination of the different elements in definite proportions by weight. Thus, in carbon monoxide, it was always found that there were 16 parts by weight of oxygen to 12 parts of carbon, in whatever manner carbon monoxide was prepared. In carbon dioxide, the combining ratio was 32 parts by weight of oxygen to 12 parts of carbon. i.e. there was precisely twice as much oxygen combined with a given weight of carbon in carbon dioxide as was combined with the same weight of carbon in carbon monoxide. It was thus clear that the units in which oxygen and carbon existed were perfectly definite in weight, and that carbon monoxide was composed of "compound atoms" each of which consisted of one carbon and one oxygen atom, which had relative weights of 12 and 16 respectively. Similarly, carbon dioxide was composed of "compound atoms" consisting of one carbon to two oxygen atoms, giving the relative proportions of 12 to 32 parts by weight. Every part of any piece of a pure chemical element has the same chemical properties, agreeing with Dalton's first postulate. And Dalton's second postulate is proved to be true by the experimental law of the conservation of mass. There was no way of detecting single atoms until long after Dalton's great theory was proposed, but the proofs which he gave were conclusive regarding the real existence of atoms. We can detect individual atoms and measure their masses and diameters, and it is found that they conform to Dalton's postulates.

The next important step in the fundamental understanding of matter was the demonstration that all atoms contain electricity, and in fact are essentially electrical in nature. That electricity could be obtained from matter in various ways, including by means of certain chemical reactions, had been known for some time when Faraday (1830) performed a series of experiments which showed that electricity was also composed of discrete "atoms of electricity" — now known as electrons. Faraday investigated the manner in which electricity was able to pass through solutions of metal salts in water, the process of electrolysis. He discovered the following facts regarding this process: (1) The weight of a chemical element which was set free from combination with another element in a salt during electrolysis, was proportional to the total quantity of electricity which had been passed through the solution; and, (2) when the same quantity of electricity was passed through the solutions of several different salts successively, the weights of the various elements set free in each case were proportional to the relative weights in which these elements combined in chemical reactions. Faraday saw that the first of these two Laws of Electrolysis was explained if the liberation of each atom of an element corresponded to the transfer through the solution of one, two, or some small, fixed, number of electrons, any given quantity of electricity thus containing a definite number of electrons. The second law was explained by the assumption of the existence of electrons, together with the known facts of the relative combining weights of different elements, since if for example the setting free of one atom of any element from combination required the passage of one electron, then evidently the weights of different elements liberated by a definite number of electrons must be proportional to the relative weights of the different kinds of atoms involved. Electrons, like atoms, can today be detected singly, and Faraday's conclusion as to the atomicity of electricity has been fully confirmed. Later in the nineteenth century, Thomson showed that all atoms contain electrons, and he measured the mass of the electron, finding it to be about 1/1850 of the mass of the lightest atom (the hydrogen atom).

The third great advance in physical knowledge achieved last century was the prediction of, and then the actual generation of electromagnetic (radio) waves. The suggestion that rapidly accelerating electric charges should be expected to give rise to electric and magnetic disturbances in their neighborhood was made by Maxwell in 1873. He found, as the result of a mathematical analysis of the conditions in the region surrounding a conductor carrying an oscillating electric charge, that when the frequency of oscillation was high enough, the more remote parts of the electric field associated with the charge would not be able to follow the changes in the field close to the conductor. Consequently, these regions of the field would break away from the oscillating electric charge, and would move outwards into the surroundings. The changing electric field would produce a corresponding changing magnetic field and vice-versa, perpendicular to the electric field, and to the direction in which this "electromagnetic" wave was travelling. Maxwell predicted that these electromagnetic waves should move at the same speed as light, but they would have frequencies much lower than those of light, with correspondingly longer wavelengths than light waves possessed. The experimental verification of Maxwell's theory was performed by Hertz in 1887: Hertz showed that the rapidly oscillating electric charges in a wire connected to an electrostatic condenser definitely produced radio waves, and he devised means for measuring the wavelengths of the radio signals. These were found to be of the order of a few meters, corresponding to frequencies of about 100 million cycles per second. The generation of powerful radio signals was later achieved by using the triode valve, which could also be used to detect and amplify the weak signals received at a distance from the transmitter.

With the later discovery of X-rays by Röntgen (1895), which arise when a beam of electrons traversing a vacuum collides with a metal target, thus causing large decelerations of the electrons, and the measurement of X-ray wavelengths by Bragg (1913) — they proved to be of the order of 1/100,000,000 centimeter—it became clear that all these waves (including light waves) were similar in nature. They were all essentially rapidly varying electromagnetic fields, differing in their respective frequencies of variation and wavelengths. Electromagnetic waves are free energy — they will travel through empty space at the maximum speed of 300,000 kilometers per second possible for any physical effect, and all decrease their intensity according to the inverse square of the distance from their source. The finite speed of these waves sets the limit on the rate at which any kind of information can be conveyed by them, and may even set the limit on the size of the observable astronomical Universe. And the finite wavelengths of even the shortest X-rays set a limit on the smallness of detail observable in matter by their use. (But since atomic particles themselves are also associated with very short waves, it is possible to detect even finer details, down to dimensions of the sizes of atomic nuclei, using high energy particles instead of electromagnetic waves).

We now consider the evidence which science has produced regarding the origination of living beings on the Earth. Firstly, there is the conclusive evidence of the fossils of many different types of plants and animals found in geological strata. These have shown that new species have arisen successively from older ones, the most recent fossils being found in the topmost strata, and the earliest fossils in the lowest strata. The absolute ages of the different strata are determined by the physical method of radioactivity dating, which is independent of any environmental factors except for the time elapsed since the strata were laid down as sediments in shallow waters. The process of evolution of living organisms is thus found to take place as a slow variation in their form during the periods of millions of years for which life has been present on Earth.

The oldest known living things have the simplest structures, and are dated to greater than 600 million years ago, in the Pre-Cambrian period. These were seaweeds which have left impressions of their forms in the rocks, but in older rocks indications of life are still found in traces left by creatures crawling over ancient mud. (Several Pre-Cambrian invertebrate animal fossils have been found recently in Australia). It is evident that most of the Pre-Cambrian life must have been soft-bodied, and consequently left little traces of its existence in the rocks after death. This is what we would expect, since the simplest living types of the present-day are without hard parts (e.g. the protozoa, polyzoa, etc.). Thus life must have originated sometime in the Pre-Cambrian, most probably in the liquid environment of the seas, during the long intervals of warm climate which have existed between the widely spaced Ice Ages of the past. The actual age of the Earth is today known to be 5,750 million years, within about 200 million years, from studies of radioactively formed isotopes in meteorites. There has therefore been a period of about 5,000 million years on this planet — the Pre-Cambrian — during which the complicated molecules of life were being built up from simple ones.

Modern chemical research has now shown that the essential constituents of living matter, proteins, are composed of enormous long spiral molecules which are assembled from the much smaller amino acid molecules obtained from the breakdown of other proteins in an animal's food. The assembly process takes place within the body cells, under the control of ribonucleic acid molecules sent out from the cell nuclei, the latter molecules being made in the nuclei according to information contained in the structure of the chromosomal genes, which carry most of the hereditary specification of the animal species in terms of their chemical structure (the remaining information being contained in the cell wall according to the latest studies). The question of how the genes of the earliest organisms came into being is probably to be answered in terms of the deposition of carbon-containing molecules upon a crystal matrix of an inorganic mineral, the organic molecules then uniting in their close proximity to give large molecules. It must be remembered that the early genes would be far smaller and simpler than those occurring in organisms today, since long evolution has evidently led to many increases in complexity of the genes. Actually, modern genes appear, according to the most recent research, to have considerable redundant portions in their lengths; that is, the specification of the species-specific characteristics of an organism appears to be repeated to an extent greater than is really necessary — this leads to greater reliability in copying of the genes however.

The formation of amino acids from purely inorganic molecules — methane, ammonia, water, carbon dioxide — has been accomplished by the passage of an electric discharge through mixtures of these gases in the laboratory. The conditions under which these experiments were performed were chosen to approximate to those which probably existed in the terrestrial atmosphere in the early part of the geological history of the Earth, when lightning discharges would have taken place frequently in the turbulent gases. Thus there appears today to be significant evidence concerning the origination of life on Earth which suggests, quite strongly, that it arose from non-living matter under the influence of natural forces. The presence of viruses on the present-day Earth — molecules, intermediate in size and other properties between the chromosomes of living organisms and non-living organic molecules — adds confirmation to the inorganic hypothesis of the origin of life.

Perhaps the discovery, as one of the major causes of disease, of bacteria (microbes or germs) in the last century, leading to the practical control of bacterial diseases, has done as much to convince people of the effectiveness of scientific methods of solving problems as have advances in any other field of scientific application. The largest credit for showing that microscopic living organisms were responsible for important human, and animal diseases, must go to Pasteur (1858-) whose researches really established bacteriology as an essential part of medicine.

Pasteur was studying the chemical substances produced during the process used in the fermentation of wine, and he noted that under the microscope the fermenting liquid was seen to contain numerous small cells without nuclei. These cells, if transferred to a solution of sugars, caused vigorous fermentation — production of alcohol and carbon dioxide — to occur, and the cells rapidly multiplied in number during the process. Pasteur therefore concluded that fermentation was due solely to the metabolic activities of enormous numbers of microscopic organisms — the bacteria. The alcohol and carbon dioxide which fermented grape juice contained were the waste products of the wine-forming bacteria, while the grape sugars were their food.

Once Pasteur had realized that bacteria could produce chemical changes as striking as fermentation, and that bacteria occurred everywhere — in soil, water, and air — he sought to find other effects which might be ascribed to bacterial action. He showed, for example, that the decaying of a beef broth after exposure to the air, was due to bacteria entering the liquid and multiplying in it, with the formation of noxious substances: a broth, thoroughly sterilized first by boiling in a closed vessel, remained fresh indefinitely, since no bacteria were present in it: (heating killed any which were in it to begin with). This observation disproved the theory of spontaneous origination of microorganisms accepted by some biologists at the time.

Pasteur now started to examine fluids taken from diseased animals and humans for possible bacteria which might, he thought, be the cause of various diseases, and in the cases of anthrax (a serious disease of sheep), chicken cholera, and a disease of silkworms he was able to see bacteria of different kinds in the microscope. (However, he could not observe any bacteria in fluid from a human affected with rabies — this disease is caused by a virus too small to be seen with the microscope: nevertheless Pasteur developed a successful treatment for the otherwise fatal disease.) These bacteria he cultured on suitable chemical media, and animals inoculated with bacteria from these cultures developed the respective diseases, proving that the bacteria were the actual causes of the diseases concerned. Since healthy animals often recover from a disease , it was evident that their bodies had mechanisms for killing invading bacteria: also, since a first attack of a disease usually rendered a second attack of the same disease on the same animal less severe than the original attack, or prevented further attacks altogether, it appeared that the bacteria themselves stimulated the body to produce something which could later render the particular bacterium inactive. Pasteur concluded that the artificial inoculation of bacteria into an animal would produce an antitoxin in its blood, which could be extracted by separating the blood serum (blood cells and bacteria removed) from the blood, and which should confer immunity to the particular disease on animals into which it was inoculated. He carried out these experiments and was delighted to find that the results agreed with his theory of immunization outlined.

Today antitoxins (effective against bacterial toxins or poisons), or antisera (acting against bacteria themselves), have been made for many bacterial diseases, thus making actual or possible the elimination of e.g. typhoid, cholera, etc., when used in conjunction with satisfactory standards of hygiene to prevent the spread of disease. We can feel fairly confident today that not only bacterial, but also virus-caused, diseases can be virtually wiped out by means of this technique of inoculation.

# V

Psychology, as an experimental science, is only about fifty years old, but already it is beginning to provide some highly significant information on the nature of processes taking place in the brain, and which are associated with behavior: the fundamental processes of thought in the higher animals are at last, after centuries of inconclusive discussion, being brought into the field of rational investigation.

The first successful psychological experiments on animals were those of Pavlov (1879-). Pavlov used dogs as experimental animals in his investigations of the mechanism of learning. It was already recognized that there existed a number of natural reflex mechanisms in animals, the purpose of which was to protect the animal from injury: e.g. when the extremities of the limbs encounter a hot surface, the limb muscles contract rapidly to remove the end from the injurious temperature. This mechanism is automatic, not involving any learning process, and the actual sequence of physiological events is quite straightforward: Heat receptors on the limb extremities generate nervous impulses on being heated, which travel along the long sensory nerves up the limb into the spinal cord where they pass across nerve junctions (synapses), setting off further impulses in other (motor) nerves going to muscles in the limb concerned, and so causing these muscles to contract and move the limb away from danger.

Pavlov showed that learning of simple responses to environmental stimuli involved a similar kind of mechanism, but that here there was a process of storage of information in the brain. When a dog smells food, there is a release of saliva in its mouth in anticipation of eating, and the greater its hungriness, the more saliva is released. If, at the same time that food is presented to the dog, a bell is sounded, the animal starts to associate the bell with food, and after a number of repititions of this process with the bell preceding the food by steadily longer intervals, the dog will salivate upon hearing the bell alone, even if no food is finally presented. Pavlov called this learning mechanism a conditioned reflex, and suggested that it comprised the following stages: (a) A simple reflex action — presentation of food causing the dog to smell, with resulting salivation; (b) the simultaneous nervous impulses caused by the stimuli of smell from the food and sound from the bell, passed across neighboring parts of the lower brain at some point in their passage to salivary gland muscles, and sound memory storage region in the higher brain, respectively: as a result, the nervous impulses in one circuit were able to affect those in the other, since nerves are not perfectly insulated from one another; (c) the two previously independent nerve circuits eventually became interconnected upon repeated stimulation, so that an impulse originating in the ear, due to sound from the bell, was transferred into nerves leading to the salivary gland muscles, producing salivation. This process of conditioning plays an important part in providing new responses in animals (including ourselves) as the changed environment requires. The conditioned reflex is entirely at the subconscious level of the brain however.

In animals there is little mental action at any higher level than this, but with the primates (especially chimpanzees and Man), there is learning, memory and thought taking place within the prefrontal lobes of the brain at a conscious level, as well as subconscious mental activity. Studies of chimpanzee behavior, undertaken notably by Kohler, have shown the mental capabilities of these animals to be considerable: chimpanzees can solve problems involving manipulation of their environment to attain particular objectives, using sticks, ropes and boxes in ways like those used by Man, and requiring trial and memory for their successful solution. But without a language to specify objects, the chimpanzees are unable to go further than what, to Man, are simple operations. There seems little doubt that the development of spoken language has made possible Man's great mental development, assisted by his inherent manual dexterity and accurate vision. Later the written language, and still later mathematical symbols, have even further advanced our mental capabilities.

Another most important series of experiments on mental activity began with the first observation, by Berger in 1929, of actual waves of electrical potential changes taking place in the brain during thought, which waves were sufficiently strong to be detected by electrodes placed on the head surface. These so-called "brain waves" were found to be of a very complex nature, but definite rhythms at frequencies of from about 8 to 13 cycles per second were present. Further experiments have been performed on the exposed brain of normal and abnormal subjects, and have revealed the sites of electrical activity corresponding to stimulation of the various senses. In its nervous circuitry the brain resembles the modern electronic computers with their switching transistors and ferrite "memory" cores — indeed these computers perform logical processes in a manner resembling that of the brain, although the computers operate much faster than the brain does and have far less separate elementary parts than the brain possesses. Future study of the computers may well teach us a good deal more about cognitive processes. But today there does not appear to be any provable reason to doubt that the mind is simply the brain in function, which implies that the death of the brain, which occurs about 10 minutes after its blood supply ceases, results in the final extinction of the mind. This of course discredits the whole idea of an immortal mind or "soul" — the basic tenet of religion. As Man is always a hopeful animal, to death, it seems quite probable that he invented the concept of a "soul" to satisfy his own wishes.

One of the primary problems facing Mankind today is the rapid growth of his numbers, at an ever increasing rate, which if it continues unchecked, without a complementary rise in agricultural production, will lead to serious food shortage in less than 100 years from now (1962). The actual limiting population which the Earth could support has been estimated at about 50,000 million people, which would mean about 1000 people per square mile of land surface, assuming that 85% of the Earth's 57.5 million square miles of land could be made available to Man (which appears unlikely). That is there would be roughly two people per acre of land, or, uniformly spaced, people would be only about 50 feet apart!

The latest available data on population give the following figures for total world population:

| *Year* | *Population* | *50-year percentage increase* |
|---|---|---|
| 1650 | 520 millions | |
| 1700 | 610 " | 17% |

| | | | |
|---|---|---|---|
| 1750 | 700 | “ | 13% |
| 1800 | 900 | “ | 29% |
| 1850 | 1,200 | “ | 33% |
| 1900 | 1,500 | “ | 25% |
| 1950 | 2,400 | “ | 60% |

If the 50-year percentage increases are plotted against the dates, it appears that they indicate: (1) A rising percentage increase in the average, from about 10% in 1650 to about 50% in 1950; and (2) a quasi-periodic fluctuation in percentage increase, in a period of about 150 years. If this curve is extrapolated to 2050, the percentage increases in world population are given as about 75% for the 50-year period ending 2000 and about 45% for that ending 2050. With these values we can calculate the approximate population numbers for 2000 and 2050 as being 4,200 million and 6,100 million respectively. The figure for A.D. 2000 is considerably smaller than the United Nations estimate of 6,300 million, which figure would appear to be reached about A.D. 2050 according to the present analysis. However, it seems rather likely that by 2050 A.D. at the latest, the Earth's human population will exceed 6,000 million, which corresponds to more than 120 people per square mile, or about one person per 5 acres of land, again assuming nearly all the Earth's land to be made habitable. Since it is more probable that, at most, about 40% of the land surface could be made available for agriculture during the next 100 years, we may expect that about 2½ acres of land will be available, on the average, for each person living in the year 2050 A.D. This should be adequate if it is properly treated, but will necessitate a very large amount of work in increasing the area of cultivated land from the approximately 10% of total land surface now in agricultural use. The main regions of the Earth which will have to be made intensively cultivable are: Central Asia, from the Caspian Sea to the west Chinese border (mainly mountainous, and semi-desert or desert); all of Arabia (desert or semi-desert); the Sahara in North Africa (desert or semi-desert); the Congo of Central Africa (tropical rain forest); most of South Africa, from the Congo to the Republic of South Africa (grassland, scrubland, desert and semi-desert); the western half of North America, from Canada to Mexico (mountainous, grassland); nearly all of the Amazon valley in South America (tropical rain forest); the eastern inland region of South America, and the southern part of the continent (grassland, scrubland, and mountainous); and the whole of the interior of Australia (desert and semi-desert, scrubland, and grassland). Along with the opening up of these vast regions, and in fact necessary for their employment, will have to go vast migration schemes to transfer people from the overcrowded Euopean, and especially Asiatic, countries to the new regions. This alone will require the formation of a world government, apart from the many other problems which will necessitate such an oganization.

We can see that the basic cause of war is the overcrowding of people which results from population increase taking place in a particular region at a rate faster than the rise in economic output, by considering the instances of Europe, China, and the United States. The European population was about 90 million in 1650; had grown to 130 million in 1750; to 270 million in 1850; and to 560 million in 1950. This great increase in population, which has taken place especially in certain countries like Great Britain, Germany, Italy, and the U.S.S.R., has meant that people in these countries have, in the face of rising economic deficiencies, either been forced to migrate to previously almost uninhabited lands overseas, or been driven to attack neighboring peoples to redistribute their own population. In Europe repeated wars have occurred since 1650, and although these have been sparked off by dictatorial individuals (e.g. Napoleon, the German Kaiser, Hitler, Mussolini), these men have always had discontented peoples who were ready to fight for new territory if they were led to do so. In China, where the inefficient agricultural methods have resulted in famines since the distant past, and where people have lived on the starvation border, worsened by disease, for centuries, there has been continued war, both internal and external. In the United States, where a large population increase has occurred since the seventeenth century, there has not been appreciable tendency to war, (the Civil War was due to aesthetic ideals, and was not undertaken by the oppressed negroes themselves), because the population rise in the eastern States was relieved by migration of people westwards within the country, together with a more than adequate rise in economic output. Until international migrations of people from crowded to sparsely populated lands are made a reality, there will continue to be war between nations.

Science gives Man increased power over his environment, which includes men themselves. But unfortunately today science is being used to aggravate the effects of war by the provision of even more destructive weapons for the political leaders of nations to use. These leaders are heavily biased in favor of the needs of their own peoples, (or are attempting to satisfy personal desires for power), and they are willing to use modern weapons of war against other peoples when they feel it is opportune to do so. Politicians do not concern themselves with the long-term requirements of Mankind as a whole, since in general their periods of administrative power are limited by their being involved to a great extent in the internal affairs of their own nations, in the conduct of which affairs they, sooner or later, fail to satisfy public wishes, resulting in their discharge from power. Only the scientists can undertake continued studies of internationally important problems, but even they are often distracted from such investigations by the nationalistic demands of their own governments (e.g. in the preparation for war), or are obliged to sell their services to enrich particular businessmen without the freedom to make available their knowledge to benefit Mankind as a whole. This situation can only be remedied by all the world's scientists insisting on complete freedom of work along lines chosen by themselves, with corresponding freedom for the complete publication of the results of their researches.

Modern medicine is dependent for its day-to-day successes largely on the scientific discoveries of the past, and must look towards science for its future advances. Actually, medicine is really a branch of science today, and medical men may justifiably feel pleased that their hopes of successful treatment of many human diseases have been so largely fulfilled by the impassionate enquiries of scientists in many different fields.

One of the earliest scientific discoveries in medicine of importance was that of the prevention of the deadly disease smallpox, by Jenner in 1796. Jenner had observed, during his medical practice, that milkmaids were apparently immune to smallpox, and upon investigation he found that this was due to their having been infected with the much less virulent disease cowpox, contracted from handling cows. He therefore prepared extracts from infected cows, which he transferred into the skin of humans. Upon later introduction of smallpox extracts into these people, no disease resulted. Jenner, although ignorant of the existence of the smallpox virus, was thus able to develop the first effective technique of immunization of human beings against a disease.

The introduction of aseptic techniques of surgery during the last century (Lister, 1865), using disinfectants such as carbolic acid, greatly reduced the mortality rate due to gangrene (bacterial infection of wounds), and the discovery of ether as an anaesthetic (Morton, 1846) made surgery approach something like a scientific discipline—the anaesthetized patient could now be operated upon without the terrible pain previously resulting, and in a condition of relaxed muscles enabling the surgeon to work with comparative ease and at an unhurried pace. Later, improved anaesthetics like pentothal, injected intravenously to produce anaesthesia within a few seconds of administration, followed by ether and oxygen, made operations not unpleasant (post-operative pain being minimized with morphine). Local operations could be done under the influence of a local injection of procaine.

The discovery of the existence of different human blood groups, mutually incompatible in transfusion between individuals (Landsteiner, 1901), was a major step forward in medicine. Now it became possible to transfer blood from healthy individuals to those suffering from loss of blood (either through accident, or during surgery), with certainty of success. Today intense study of the blood is being carried out to determine the causes for its abnormal clotting behavior in thrombosis, and to investigate the whole mechanism of immunity, afresh.

With Pasteur's work on bacteria, followed by that of many other researchers, the ability of medicine to control the majority of infectious and contagious diseases through preventive immunization, and chemical or physical destruction of bacteria outside the body, was greatly increased. The exact manner of transmission of the different disease bacteria was determined, and their resistance to antiseptics and disinfectants was measured. The discovery of the first drugs capable of attacking bacteria within the body, (e.g. salvarsan for syphilis, Ehrlich, 1910), and then of the general antibiotics, (penicillin, Fleming, 1929; sulpha drugs, tetramycin, etc.), virtually conquered the stubborn staphylocci and streptococci which cause boils, throat infections, etc., and the pneumococci causing pneumonia, and made practicable the treatment of tuberculosis.

Almost immediately after the discovery of X-rays by Röntgen (1895), these body-penetrating rays were used to produce shadowgraphs revealing the exact nature of bone fractures and the location of metal objects accidentally imbedded in the body. With the use of X-radiation opaque substances introduced in solution into various body organs (heart, stomach, intestine, kidney, etc.), the sites of any defects in such organs could be delineated prior to operation, leading to increased success in treatment. More lately, the use of radioactive isotopes introduced into the body, has led to even greater diagnostic ability: e.g. in locating brain tumours, in measuring lung efficiency, and in determining blood circulation.

The surgeon is nowadays able, through the development of such apparatus as the heart-lung machine, the artificial kidney, new surgical instruments (e.g. the blood vessel stapler), the electroencephalograph for examining abnormalities in brain function, the cardiograph, surgical cryogenics (freezing of organs to slow metabolism), etc., to undertake operations of a degree of difficulty quite unattainable previously, even in such inaccessible regions as the interior of the heart.

And today an immense quantity of fundamental research is being done in the attack on the virus-caused diseases. Already poliomyelitis is conquered with immunization (Salk, 1954), and the work on the common cold is approaching a very hopeful stage in its efforts to rid Man of this troublesome ailment. The work on cancer has been quite successful also, with several practical methods of treatment of early-stage cases now available, including X-ray and radio-isotope irradiation of tumours, complete surgical removal of diseased areas, and irrigation of cancerous organs with solutions of certain chemical compounds.

# VI

Although it may not be fully realized as yet, Man has already started to carry out international scientific programmes, and these programmes have had a considerable success both as regards the scientific results achieved, and in furthering cooperation between scientists of the various nations concerned. Several of these large collaborative efforts are on a continuing basis, e.g. the study of the Antarctic region, the World Health Organization malaria eradication campaign, and the Central European Nuclear Research Laboratory in Switzerland. An international study of the Indian Ocean is starting next year, as also is the International Year of the Quiet Sun in 1964. And, of course, international scientific conferences are being held in ever greater numbers annually, in the major cities of the world, often organized by the various international scientific oganizations.

The large-scale research programmes undertaken during the International Geophysical Year (1957-1958) formed the most intensive drive to increase knowledge of the Earth ever accomplished by Man. During the 18 months of the IGY, thousands of scientists, from several tens of different countries, combined their specialized techniques and abilities to obtain world-wide data in many different fields of research. These included studies of the upper atmosphere—aurorae, night-sky light, ionospheric behavior, high-altitude winds, chemical constitution of the outer atmosphere: the placing of artificial satellites in various orbits around the Earth, carrying equipment to measure cosmic rays from outer space, X-rays and ultra-violet light from the Sun, the terrestrial magnetic field, the frequency of micrometeorites in space; and for use in studying continuously the density of the atmosphere at great heights, and the shape of the Earth: the intercomparison of very precise absolute measurements of gravity made at numerous points on all the continents: the practically continuous observation of the Sun with equipment to detect and record solar flares optically, and intensive observations of sunspots, prominences and the solar corona using the latest optical and radio techniques: the study of the geomagnetic field at the Earth's surface, employing highly sensitive instruments like the proton magnetometer: the investigation of radio-wave propagation below and through the ionosphere, and its dependence on solar activity: the obtaining of global data on weather over both land and seas: the world-wide observation of earthquakes at many seismological stations: and the obtaining of simultaneous observations in both the Arctic and Antarctic to investigate correlations of polar ionospheric fade-outs, aurorae, etc., in the two hemispheres.

Some of the outstanding results of these studies—data collected during the IGY, when the Sun was at maximum activity, was so extensive that it will take years to analyze fully—were the discovery of the Van Allen radiation belt surrounding the Earth (an enormous doughnut-shaped zone of intense radiations lying some thousands of miles from the Earth's surface, inside which particles from the Sun become trapped due to the geomagnetic field); the discovery of a close connection between aurorae in opposite polar regions, and that the aurorae originate in the leakage of charged particles from the Van Allen belt into the upper atmosphere; the determination of a considerably more accurate value for the ellipticity of the Earth than previously available, and the indication that the surface of the Earth is in fact not even a spheroid, but has unequal diameters in the equatorial plane also; and the establishment of the great thickness of the Antarctic ice cap, and the actual distribution of land beneath the ice.

The total eradication of malaria, which used to affect 350 million people in the world 15 years ago, with several million deaths annually, is the aim of the World Health Organization programme begun in 1957. This effort in applied science, which is making use of already available knowledge of malaria and its transmission by the Anopheles mosquito, is an excellent example of the enormous progress which can be achieved in an international plan of real importance to Mankind as a whole.

The life-cycle of the malarial parasite, the microscopic cause of the disease, is fairly complicated and includes stages in both man and mosquito. When an infected human is bitten by a mosquito, parasites circulating in the person's blood are transferred to the insect, in which they undergo development into a stage capable of reinfecting humans. The parasite is reinjected into humans by the mosquito biting them, but between its blood meals the mosquito settles on any available vertical surface to perform digestion. Consequently spraying of all wall surfaces in every human habitation in malarial areas with suitable insecticides (e.g. D.D.T.), so killing the mosquito vectors, breaks the transmission mechanism. In 1953 W.H.O. control campaigns had succeeded in protecting 6 million people, but the development by several mosquito species of resistance to insecticides made it evident that only worldwide eradication was likely to rid Man of malaria permanently. The main regions in which malaria is still prevalent are Central, and much of South America, most of Africa( except the Republic of South Africa), parts of Arabia, much of the Near East, India, China, and South-East Asia. By 1961, of 1,420 million people (half the world's population) exposed to malaria, 317 million were freed of the threat, 710 million were involved in active eradication programmes, 170 million were in areas planned for attack soon, while 223 million were totally unprotected. The eradication of malaria in any area takes about eight years altogether: the first year is the preparatory phase; the second to sixth years, the attack phase, involving total-coverage spraying (interruption of transmission of the parasite is achieved after about 2½ years); and the sixth to eighth years, the consolidation phase, in which only focal spraying is necessary (the infection rate is reduced to only 1 person in 2,000 after about 5 years). After the eighth year, the work comprises maintenance of freedom from malaria by detection and treatment of every individual case of the disease, and, if necessary, blood examination of the entire population to locate any remaining malaria carriers.

The elimination of malaria may also be assisted by the issue of chloroquinine-medicated salt to all people living in areas in which spraying is not completely effective. Malaria should be eradicated from Europe in 1962, and from the Americas, North Africa, and much of Asia within ten years. But success in much of Africa is slow at present. The degree to which so many nations, including the backward ones, are collaborating in this great effort is indeed encouraging to all who look forward to the same sort of thing in other fields of scientific application for the benefit of all people.

A great achievement for science is the recognition by twelve governments of the important research investigations already carried out, and in progress, in Antarctica, resulting in the reservation of the continent for 30 years solely for scientific research. This continent, some 1½ times as large in area as Australia, and largely covered with glacial ice to a depth of about 7,000 feet, is probably the southern portion of the land mass known as Gondwanaland which comprised all the present continents before they started drifting apart about 300 million years ago. The Antarctic ice mass is the largest on the Earth today, representing about 90% of the world's ice. Consequently it has a marked influence on world climate and on the ocean currents in the Southern Ocean surrounding it, so that for a proper understanding of world meteorology it is necessary to study the Antarctic weather thoroughly. The ice is so massive that it has depressed the underlying rock below sea-level in some places, the continent's roots being thus pushed down into the plastic layer below the Earth's crust. If all the Antarctic ice melted (which appears to be somewhat unlikely on present evidence), the sea level over the world would rise between 130 and 200 feet—which would submerge many of the major cities of the world. It is most desirable to discover whether the ice is growing or diminishing; work on this is going on continuously in the Antarctic now. Since the Antarctic ice is flowing outwards from the pole in all directions, and ice is a crystalline material resembling rock in its physical properties, but is much less rigid than rock, study of the flow of the huge Antarctic ice-cap can provide information on how rocks may flow in the crust. This will lead to better knowledge of the causes of earthquakes, which is bound to be of value to all countries located in earthquake zones.

The Antartic (Southern) Ocean is very rich in plant and animal life, from the microscopic plankton to the giant whales. Although Man is gradually making the whales extinct, the vast food supplies available in plankton could possibly be of importance in the future when land for agriculture begins to run short. Investigation of the life in Antarctic waters is therefore a significant part of the reseach programme there.

The exploration of space, started in 1957 with the orbiting of an artificial terrestrial satellite at an altitude of about 200 miles, is now progressing rapidly with several other countries besides the U.S.S.R. and the U.S.A. also contributing toward the general effort. The latest satellites are providing very large quantities of data on world cloud distribution; are measuring the heat radiation lost by the Earth into space; and are being used to study the Sun from above the atmosphere in a range of wavelengths from X-rays to radio waves. In addition, two rocket probes have reached the Moon, and others are on their way to Venus and Mars. There seems little doubt that exploratory vehicles will be operating on the lunar surface soon, and that important physical information on Venus and Mars will be obtained in due course. The nature of space studies is such as to provide scientists with a strong incentive to join in international collaboration, which may lead to the Moon being held for research for 10 or more years before any attempts are made to found colonies there.

The development of world-wide communication systems, based on the relaying of telephone and television signals from surface transmitters via satellites to distant receiving points around the Earth, is being energetically pursued at present with successful first results, and would make possible important practical educational facilities for peoples lacking modern skills to help them achieve efficient economies.

## VII

In this chapter I wish to point out the very real possibility of solving the major world problems confronting Man today by use of the scientific method. These problems may be summarized as being: major diseases (cancer, thrombosis, mental and auto-immune diseases, malaria—the last is already being eradicated); food production; technological knowledge availability; mineral supplies; nuclear reactor fuels; rapid transport; information transfer; irrigation; population limitation.

In a modern country the primary diseases causing death and illness are cancer in its various forms, thrombosis and related heart ailments, nervous and mental disorders, and the various auto-immune diseases (rheumatism, arthritis, etc.): parasitic, infectious, contagious, and deficiency diseases still affecting people in backward countries, the most important of which are malaria, bilharziasis, roundworm and hookworm, yellow fever, smallpox, typhoid, cholera, gastro-enteritis and colitis, trachoma, leprosy, tuberculosis, pneumonia, influenza, the venereal diseases, yaws, beriberi and pellagra, can all be eliminated by known methods of sanitation and hygiene, and a nutritious diet. Although the causes of cancers in Man are still undiscovered, many important findings have been made recently, and leading researchers have concluded that successful treatment of cancers is likely to be generally possible fairly soon. For example, lung cancer has now been proved to be associated with smoking—the average smoker loses about eight years of life through indulgence as compared with the non-smoker. Other agents, such as motor-vehicle exhaust, are probably also involved in lung cancer. The detection and elimination of carcinogenic substances should not be beyond our capabilities — the virtual absence of cancer in non-industrialized communities (e.g. feudal Japan) shows that cancers are diseases of civilization. Similarly, coronary thrombosis appears to be definitely aggravated by stress present in life in large communities: there is almost certainly some clot-causing substance released into the blood during the disease, and this has yet to be identified. But it would be possible to considerably reduce living stress by limiting the sizes of urban populations to perhaps 50,000 or so, with adequate space allowed between buildings for gardens. According to recent work on the arthritic diseases (notably by Burnet in Australia), the basic reason for these is a breakdown of the normal immunity mechanism of the body. The white blood cells, instead of attacking only foreign bacteria, attack body cells—apparently because the cell surfaces receive some chemical substance making them "foreign" to the white cells. Blood from arthritics has been found to contain pain-causing substances, and the tendency to these diseases is inherited. Their cure seems to lie in chemotherapy involving the neutralization of substances generated in error by the body itself: the further study of this problem is also likely to lead towards successful methods of tissue transplantation, since this is limited at present by the immune reaction. Mental and nervous diseases are not today regarded as impossible of treatment with success. Parkinson's disease —a serious neuro-muscular disorder—is now treatable by surgical freezing of the responsible cells in the brain. Many psychologically disturbed people can be assisted to return to health by psychiatric treatment (although at least one noted authority has expressed doubt as to the efficacy of present-day methods here). And the seriously mentally ill —e.g. those with schizophrenia—may be treatable fairly soon as a result of advancing knowledge of the true nature of mental illness: e.g. recent work suggests that schizophrenia may be caused by environmental circumstances, which might be brought under control.

The production of enough food to feed every person on the Earth to a fully satisfactory standard is entirely within our abilities today. The primitive soil-scratching agricultural methods of the Asiatic and Africian peoples can be replaced by mechanized agriculture with a great gain in efficiency of production. Comparison of figures for the United States of America (where 12% of the population produce more food than is required), and for India (where 70% of the population does not produce enough food to raise the country above the malnutrition level), shows immediately the far greater effectiveness of modern agricultural techniques. In order to utilize these properly it is necessary to reclaim the at present semi-desert and rain-forest regions of the world, to move many of the people from Asia to settle in new areas, and to provide them with full technological knowledge needed to reach the modern standard of food production.

To bring the world's backward peoples to a state of industrialization in which they can make many of their own material requirements, and provide trading ability with other countries, technological knowledge is a necessity for them. The basic knowledge needed—modern methods of locating and mining minerals, steel and alloy production, transport and road construction, water collection and distribution, electric power generation and distribution, making of cement, bricks, and glass, housing methods, and the mechanization of agriculture—is already available to us. It is evident that the onus lies on the leading nations to provide this technical knowledge, not because of any moral duty towards the undeveloped nations, but because the advancement of all peoples to a roughly equal standard of civilization is essential for the removal of the basic cause of war—which would affect the highly developed countries most seriously.

Large new deposits of metal ores—especially of iron, copper, aluminum, manganese, nickel, cobalt, lead, zinc and tin—must be located in this century if large-scale technological progress is to be possible. And we must be sure of further supplies to last far into the future also. So far mineral prospecting has been undertaken chiefly for visible surface ore outcrops, although the search for petroleum, (and more recently for ferrous ores), is now being undertaken in deep rock strata. With the highly precise geophysical exploration techniques now available, including the gravimeter, seismometer, magnetometer, and electromagnetic detector, the last two of which can be operated from aircraft, there seems little doubt that whenever ores exist beneath the surface, we shall be able to find them. The enormously greater volume of rock brought within reach of investigation with these modern techniques, combined with the success of discovery of much oil and at least one new ore body already obtained, lead one to expect that supplies of the economically important minerals will be available for a long time yet.

With regard to world energy sources, the main ones for consideration are: (a) Nuclear fuels; (b) Petroleum and coal; (c) Solar radiation; and (d) Hydroelectric power. Petroleum, although being found in large quantities still, cannot last for very long as a primary energy source, and coal is already being worked out in several countries. A considerable further development of hydroelectric generation is possible in countries with even only medium-sized rivers, and this power source is essentially permanent once its use is started. The direct use of solar light and heat to produce electricity is now approaching a real possibility through the use of silicon solar cells: if these can be made in enormous numbers, and at a low cost (something like 100,000 cells being needed to produce one kilowatt of electricity), and assembled over significant areas in sunny regions of the Earth (about 2 acres of surface are needed to generate one megawatt of power), then solar energy will become a dependable permanent source. But the main energy source of the future must be that derived from uranium, thorium, and possibly water, in reactors. Enough good uranium and thorium ores are available for some time yet, (and further ores will most probably be discovered using airborne scintillometers), but the long-term nuclear fission reactors will have to be operated on uranium extracted from granites, in which there is an inexhaustible amount. Alternatively, if the construction of a hydrogen-fueled nuclear fusion reactor is successfully accomplished, of which there appears to be some hope now, then the oceans will provide an inexhaustible supply of heavy hydrogen. In either case, we have enough nuclear fuel to last for several thousand million years—longer than the Earth will remain habitable as the Sun slowly rises in temperature.

The means for the effective distribution of materials and manpower over the Earth are essential for a general world-wide economy. Minerals and food have to be moved from places of mining and production to places of use, over both short and long distances; and people have to be moved from place to place as their work requires, and many people will have to be moved into new areas undergoing development. Both very fast large, and moderately fast small, aircraft are needed, as well as large capacity marine cargo carriers, and powerful and small mobile surface (land and water) vehicles. In the air, the jet powered aircraft, with later the ramjet for very high altitude, very fast, machines, will largely replace the more cumbersome propeller aeroplane, even for medium distance flights, since the problem of reducing the takeoff speed for smaller jets can be solved now. For short flights, the single-engine light aeroplane can compete economically with large motor cars, and provide a greater speed at reduced danger. Where surface movement across land and water is required, the rapidly evolving hovercraft will replace separate land and marine transporters: these new machines, in sizes over 5,000 tons, may even be capable of oceanic crossings. Speeds of up to 100 m.p.h. appear quite possible. Hydroplane-equipped vessels, with speeds approaching 100 m.p.h., will probably also be used for passenger carrying across enclosed seas and lakes. For long-distance cargo transport across oceans, nuclear-powered submarines towing cargo carriers, at depths of about 100 feet to be out of the surface wave zone, should make practicable rapid movement of heavy and bulk freights at speeds around 60 m.p.h. at reasonable cost. Such cargo submarines would be easily controlled at sea, safe (using long-distance asdics to locate obstacles at sufficient ranges), and could carry oil, chemicals, and refrigerated cargoes easily. On land, the petrol driven motor car will most probably be replaced by fuel-cell powered vehicles. These produce no harmful exhaust gases, are very efficient, and can be run smoothly at speeds from zero to the maximum safely possible on roads, since the propelling unit is an electric motor.

The rapid transfer of information between points at all distances up to many thousands of miles apart is absolutely essential for the best possible coordination of world economic activities. The solution to the most difficult problem—that of information transfer over distances greater than about 100 miles—lies in the use of satellite relay stations orbiting the Earth. The "random orbit" system, employing about fifty small repeaters about 500 miles above the Earth's surface, will make possible the transmission of voice and data (binary numbers) between any points on the Earth, with complete privacy for those using the satellites, and with transit times less than one hour. The "three station" system, having 3 large relay satellites spaced at equal intervals along the equatorial plane of the Earth, and at 22,000 miles distance, will provide virtually instantaneous voice and picture (television) transfer between important cities possessing the necessary large transmitting and receiving equipments.

In many dry regions of the world, irrigation could be accomplished by utilizing nuclear power to pump fresh water, obtained by electrolytic desalinization of sea water, into canals or pipes. The construction of irrigation networks could be done with diesel digging machines, and electricity for water desalting could be generated by solar cells or by the nuclear reactor. The desalinization of sea water is now perfectly feasible at a moderate cost, and is the only practicable method of providing large quantities of water to desert areas where there is no subterranean water available.

Serious efforts to limit the rate of population growth in the new nations, in which this rate tends to be very high soon after scientific method is first applied to the food and disease problems, are very desirable. The more the birth rate can be lowered, the fewer individuals there will be for the working population to support, so lightening the economic burden. Modern methods of controlling the birth rate, including voluntary sterilization, are able to do so effectively, as is evidenced by Japan the population of which is growing at only a moderate controlled rate; whereas the Chinese and Indian populations, with population densities only a quarter and a half that of Japan respectively, are growing at rapid uncontrolled rates. Since China and India have not only rapid population growth rates, but also very large populations (700 and 436 millions respectively in 1960), it is most important that these two countries adopt effective birth control immediately. Pakistan (population 87 million) and Indonesia (population 90 million) must be included also as needing immediate birth control measures. The nations of Africa, Central and South America (north region), and the Mirdle East, although having low population densities at present, also have rapid growth rates, and will therefore have to control these fairly soon.

# VIII

What, now, are the chief obstacles to a rational application of science to world problems? It appears to me that they are as follows: (a) Nationalism; (b) Communism; (c) Socialism; (d) Religions; (e) Prejudices; (f) Governmental short-term policies; and (g) The arms race. If we take these in order (not necessarily of importance), then I think that we can make the following remarks on them.

Nationalism, although a good thing so far as it encourages a people to work towards common goals for the prosperity of their country, is a hindrance to any nation that sees in it justification to permit attempts to acquire territory of other nations by force. History has shown that severely nationalistic countries, such as pre-war Germany and Japan, have not gained additional territory despite their efforts to do so — indeed if a nation subjects another unwillingly to its rule, the subjected people are bound to hold grudges against the aggressors so long as they are thus ruled. The only valid way in which a people living in an overcrowded land can increase the territory available for their settlement, is by agreement with other nations to arrange large-scale population transfer to previously uninhabited land in sparsely populated countries. Underpopulated countries should appreciate the advantages of acquiring additional population, provided that the immigrants are free of serious disease and are hard working. There is, in the present-day world, no real justification for the sort of excessive nationalism which we have seen in the past.

Communism, by its complete denial of individual freedom, is without doubt a very serious obstacle to the use of Man's scientific abilities to solve his world problems. For science is based on complete freedom of work and discussion by and between all scientists, and the open publication of all research results. This is in accordance with the fundamental aim of science—to discover the factual, objective, truth in all things, irrespective of individual subjective opinions. Thus the attitude of communism towards individual freedom cannot be tolerated by any true scientist, or in fact by any clear-thinking human being.

Socialism is certainly a hindrance to scientific application for several reasons. Firstly, the idea of a government taking control of important parts of its nation's economy, like railways, which is based on the view that these are better run by government than privately, is false: once the competition normally present between companies providing the same service is eliminated, their is no incentive for individuals in the service to give their best efforts to it. Secondly, the socialistic concept of enforcing the cooperation in governmental programmes of individuals with special abilities, against the wishes of these individuals, is completely unjustified: socialist governments should recognize that specially-skilled individuals are entitled to give their services to whomsoever they themselves consider advisable, and to receive the maximum reward for doing so. Thirdly, in their provision of social security for all, financed by compulsory contributions from every working person in the nation, socialist governments remove the stimulus otherwise present to encourage people to save for themselves: this is psychologically unsound.

The main obstacle presented by most religions to the full utilization of scientific knowledge and method is that religions advocate an (unproved) faith in superhuman power to solve Man's terrestrial problems — in complete opposition to the advocacy of science that we should rely on our own rational abilities for this purpose. The attitude of any person who concedes with the religious viewpoint, while being fully aware of the opposite scientific one, can only be stated to be entirely irrational. And any scientist who accepts both scientific method and religion and holds them to be compatible, must certainly be deceiving himself. For to any intelligent person who has examined the claims of these two opposing philosophies of life, without preconceived bias, it is perfectly clear that there can be no compromise between them on the basic question of rationality.

A continual impediment to the advance of applied science lies in prejudice of one group or people against another. A good example of this today is the manner in which the white races of the world regard the yellow and black races as in general genetically inferior to themselves. There is no valid evidence to establish this, although there may be significant racial differences in intelligence between certain peoples. However, for the present we must not artificially produce bias against any human or group of humans.

Another factor which makes difficult the large-scale, long-term, application of science to world problems, is the generally quite limited time for which most governments remain in power, with consequent short-term economic policies for their countries. Very few governments give support to researches planned to solve problems which will become important ones more than about five years in the future. Since there are very important problems of this nature, among which may be listed the world population growth, the recovery of metals now discharged into the sea as waste, and the large-scale reclamation of arid and rain-forest zones, and it is clear that present-day national governments are not capable of financing the necessary researches, there is here a definite need for an international body to carry out such work.

Finally, the current arms race between East and West is a strong block hindering world-wide use of scientific method for peace, since the enormous cost in materials and human effort involved on both sides is removing the opportunity to devote adequate energy to solving peacetime problems. It is admittedly impossible for either the U.S.S.R. or the U.S.A. to disarm in the face of possible attack, which will remain present so long as the U.S.S.R. maintains its stated objective of world conquest by communism, and the U.S.A. continues to gather ever greater material wealth for itself, without giving other undeveloped peoples the technological knowledge they need to achieve a reasonable standard of civilization. There seems to be no real likelihood of breaking the materially wasteful arms race except by a unison of the world's scientists to inaugurate a world government.

# IX

The great advantages of a world cooperation based on science are easily enumerated. Firstly, there is the universal validity of scientific knowledge: all intelligent people can verify the recognized conclusions of science for themselves. Secondly, there is the objectivity of science: since, in science, only objective reality is accepted, we can feel sure that scientific knowledge is free of errors of thought as far as the human race can eliminate these. Thirdly, there is the proven success of scientific method in bettering human welfare on the Earth. No other philosophy exists in the world which can approach that of science in respect of these highly important merits.

It is obviously a prime essential of any philosophy which is to be considered as a possibility to unite all people, that the basic ideas will be provable to all. Science satisfies this requirement completely, since, as everyone who has studied even elementary science knows, every scientific answer to a problem is obtained or verified by experiment, and the correctness of the conclusions reached through experiment are demonstrable by repetition of the experiment. Each experiment to decide a given question, when performed under identical conditions, always provides the same answer irrespective of the experimenter conducting the experiment. Scientific education consists of teaching each student that: (a) He or she must not accept as true or false anything which cannot be experimentally proved to be so; (b) The validity of every scientific statement can be proved by the student himself by the performance of the appropriate experiment: full details on how to do the experiment are given by the original scientist who devised it; (c) The actual performance of a considerable number of experiments by the student, all of which give the expected conclusions, then enables the student to appreciate that he can reasonably accept as correct the results of other experiments which he has not done for himself; (d) To make a scientific discovery one can start either from an observation of a natural event or fact which is unexplained, or one can devise a question about Nature oneself; (e) One next invents an hypothesis to explain the observation, and one sets up and performs an experimental test of this hypothesis or of the question devised; (f) The result of the experiment provides the answer to one's question, or proves or disproves one's hypothesis; (g) In advancing scientific knowledge it is important to be aware of all previous work in the particular field which one is investigating, and in publishing one's researches full reference to all authorities quoted must be given.

In essence, science teaches that to obtain reliable new knowledge one must be critical, able to experiment carefully (in general), able to generalize from one's knowledge, observant, curious, willing to accept experimental proof as final, and well read. The scientific method of dealing with problems is employed by all scientists, in whatever field they are working. The particular science, and the branch or branches of that science, in which each scientist does his research, is usually decided by the individual according to his early interests and his natural abilities for special work. The scientist, if fully accepting the principles of scientific method, is unwilling to reach definite conclusions on any matter, until the necessary research has been done to provide the factual basis for conclusions. He is also always ready to consider the bearing of any new experimentally established facts on previously accepted theories and laws of science, and will modify these laws or theories in accordance with the new knowledge when it shows this to be necessary.

The objectivity of science describes very well the world picture of the complete scientist: he sees the material world as reality, with himself as part of that reality. Of all else he is uncertain, and he must, for the present, reject the non-material as representing truth, since only in the material world can he devise acceptable proof of his conclusions. It is particularly striking for anyone who examines the history of Man's evolving thought, to notice how all his religions, ideologies, and philosophies of the past, and those of the present, have included unprovable bases, whereas the scientific philosophy is virtually free of this logical fault in its structure. For, from our knowledge of the working of the human mind, which we have only in this century begun to understand, we now know that we cannot rely on the correctness of our own thoughts alone, in trying to solve the most difficult and important problems facing us. In every question of the truth we must test our ideas against Nature herself, and we must compare our conclusions so obtained with those of others in order to check the correctness of our interpretation of our experiments. Repeatedly in the past has Man been led to reach false conclusions because he was unaware of the subjective errors affecting his thinking activities; the best that we can do today, now that we recognize these errors, is to demand objectivity in all the conclusions which we accept as truth. We also recognize, unlike in previous philosophies, that there is no such thing as absolute truth, but that as our knowledge increases, the concepts which we regard as being true will require modification. It is only possible, at any one time, for us to say that our present concepts are more true than those of the past; that is, we can accept the relativity of truth only. We can never claim to have reached finality in anything.

For all people who are looking for a better way of life on Earth, which means in fact a large part of the world's population, the well-established capability of science to provide satisfactory solutions to problems of many different kinds is a very strong point in its favor. No other existing human way of thought-with-action has been able to even suggest ways in which the enormous problems of Mankind — population growth, nutrition, disease, industrial economics, migration to undeveloped lands, and war — could be solved. But science has given us successes in so many fields that it would take a long time to mention them all, and in some fields great successes beyond the fondest hopes of the ancients. Such are: an understanding of the nature of the Universe; knowledge of the source of the Sun's energy, and the release of nuclear energy for ourselves; knowledge of the interior structure of the Earth, of the formation of its surface features, and of its age; an accurate conception of the evolution of life on Earth from primitive forms, including the actual ages of many of the ancestors of modern species; considerable knowledge regarding the working of the human body; precise knowledge of the causes of many diseases, and of means for curing them; the ability to travel by land, sea and air at high speeds; the ability to communicate over great distances at the speed of radio waves; a remarkable understanding of the structure of matter;

knowledge of how to exert enormous mechanical forces; the ability to see objects beyond the limits of human vision; and knowledge of how to create new materials for our use.

# X

Assuming, then, that for the decisive reasons given in the last chapter we have decided to have a world scientific cooperation, what are the requirements for this, and what would be the first tasks of a world government? I think that the main requirements for a world cooperation based on science are: The adoption by scientists of an unbiased attitude towards nationalism; the giving by scientists to reason the only weight in solving problems, implying the rejection of non-communicable (subjective) knowledge as a guide to action; the bearing by scientists of their responsibilities in a world government, and their refusal to develop further war weapons; the organization of the world's leading scientists into a body to insist on the formation of a world government; and the formation of a world government of individuals agreeing to apply scientific method to world problems, this government to be empowered by all nations to handle all internation matters (national governments being reduced to local control). The first tasks of a world government appear to be: The removal of national barriers to individual and trade exchanges; the provision of primary power sources everywhere; the world-wide establishment of medicine; the redistribution of population; world land reclamation and use; world agriculture and oceaniculture; the distribution of foodstuffs and minerals to all people; world education and world language; the opening to all of the opportunity to study scientific method; the discrediting of non-scientific (unreasoned) methods of solving problems; the encouragement of intelligent thought in all people, especially towards scientific reasoning; the recognition and reward of scientists.

If the scientists of the world are to unite to demand world government, they must assume an unbiased attitude towards nationalism everywhere: that is, each scientist must remain uninfluenced by nationalistic demands of his own country. The scientist must accept only the world government's policies, which will be concerned with total human progress alone. It is also essential that all scientists should accept only reason in solving world problems, rejecting non-scientific knowledge as a basis for action: for unless they do this, they will be working under different, conflicting assumptions, and will be unable to produce a world unity. Furthermore, scientists must be willing to bear their share of responsibilities in a world government, despite their research and teaching commitments: for they possess the greatest reasoning abilities of any human group, and the world government must be able to rely heavily on the support of all scientists whenever needed. The scientists must, in addition, cease advancing national military capabilities, and must refuse to develop any new weapons of war.

The first step for scientists to take, after accepting the principles mentioned in the previous paragraphs, is, I would suggest, the organization of our leading scientists into a body which would be capable of making an insistent demand to all national governments for the formation of a world government. I believe that our leading scientists would agree to constitute such a body, if the majority of the world's scientists were willing to support it. Further, I do not think that any individual national government could refuse to accept a demand for world government, if this were made by such a body as mentioned: the world's scientists, since they form the only means whereby national governments can make appreciable economic progress, have the power to obtain the agreement of all governments on the acceptance of a world government.

The formation of a world government could then be started by the collaboration of all individuals agreeing to apply scientific method to the solution of world problems. Such individuals would include scientists, engineers, medical men, some lawyers, and a few politicians. A permanent central office would have to be formed, where all data on individuals would be maintained for reference: once this had been established (perhaps in London), it would be possible to prepare a list of the best qualified individuals which would then be submitted to all for selection of the members of a world government by vote. In order to maintain the world government continuously at highest efficiency, its members should be obliged to resubmit themselves for election at intervals of about two years, in competition with new individuals placed on the voting list by selection as for the original members. The world government would require to be empowered by all nations to administer all inter-nation matters, the respective national governments being then left to manage local problems only.

The initial tasks for a world government would then be commenced in some such way as the following:

The removing of nationally imposed barriers to the free passage of individuals and goods between different countries. I would suggest that all scientists, engineers, and medical men be granted international passports enabling them absolutely unrestricted travel to all countries: these passports could include details of the qualifications of the bearers, and would constitute proof of their capabilities and unbiased outlook. If this idea were made effective, the consequent increase in general respect for scientifically trained individuals might well lead to many more making visits to other countries, with direct benefit to such countries. The abolishment of national trade restrictions (duties) on all kinds of goods, is essential to the attainment of a distribution of goods to meet the requirements of all countries. The retaining of artificial trade barriers merely encourages inefficiency in the production of goods, since if one nation cannot produce a particular commodity as cheaply as another can produce the same commodity of equal quality, the former nation should endeavor to reduce its production costs to enable its products to compete with those of the latter in free world trade.

The construction of adequate primary sources of electrical power everywhere in the world is a preliminary step towards the raising of the standard of living of all countries, especially the presently backward ones. Such primary power sources should be considered for their long-term usefullness and ability to generate power at the lowest possible cost; they should be located at the best positions within each country for supplying the needs of the population. The chief types of power source would be hydroelectric plants, nuclear (fission) reactors, and direct solar energy converters. A detailed survey of all available possible sites for large power sources should be carried out first throughout the world.

Following on with the present World Health Organization malaria eradication campaign, similar campaigns should be planned and put into operation for each of the other diseases which are known to be eradicable using present techniques. Along with this work should go a thorough education of all people in practical hygiene and the safe treatment of waste products. The successful carrying out of medical programmes in cooperation with the populations concerned would be a strong factor towards bringing all people to accept scientific government.

Since overcrowding of people in small regions is a primary cause of many troubles including war, the redistribution of populations must be carefully considered as soon as possible. Two aspects to this problem exist: one is the movement of people from crowded to under-populated countries, which is important both for relieving stress in the densely populated countries and for advancing economic development in the sparsely populated ones: the other is the transfer of people from large cities to small towns in the same area of one country, in order to eliminate the adverse psychological stresses resulting from living in large population centres. It is not necessary today, in view of the speed of modern communications, for people to live in great concentration for effective economic activity; probably cities no larger than 100,000 in population would generally suffice, and these could have adequate transport space and open areas, impossible in very large cities.

Large-scale projects for the reclamation of the presently unused lands in the whole world, and the starting of agriculture on these lands, must be organized. The enormous regions of the Sahara, the Congo Jungle, the Arabian Desert, the Amazon Basin and the Australian Desert, could be opened to settlement by the use of modern techniques. These would include irrigation of desert regions with desalinized water obtained from the sea (Sahara, Arabian and Australian Deserts), and rain water piped from artificial lakes in adjacent rainy areas (Sahara, from the Congo; Australian Desert, from the Northern Territory); the use of underground nuclear explosions to construct large dams for water storage; the use of small portable nuclear reactors for electric power generation needed in the clearing of large forests; the employment of diesel-engined earth-moving equipment in building roads; and the full support of the reclamation teams by appropriate health measures. These huge rain forest and desert reclamation schemes would be well suited to being carried out by military personnel, which would no longer be needed to bear arms once a world government were in existence. When the project areas had been brought to a suitable state for agriculture, land could be offered to individuals from overpopulated countries for permanent settlement.

The production of food, both from the land and from the sea, must be advanced everywhere with the help of the latest methods of cultivation. Agriculture can be greatly improved in the backward countries by the use of machinery (e.g. China has at present only about 10% of its agricultural land under mechanized cultivation). Similarly, the collection of fish (and perhaps plankton) from the oceans should be based entirely on adequate research regarding the distribution of sea organisms, combined with electronic detection devices used in large ocean-going fishing vessels (c. 1,000 tons). The artificial breeding of fish to the free-swimming stage should be carried out in coast sea-water lakes, from which the young fish would be transferred to their natural habitats by special vessels.

The basic foodstuffs needed by every person for correct nutrition should be made available in all countries by the transport of food from regions of surplus to those of deficit. Similarly, the primary minerals (iron, copper, aluminum, lead, zinc, etc., ores; chalk, coal for coke, crude oil) should be distributed to countries lacking them to advance industrial development there: these countries could then return manufactured goods to the countries providing the raw materials on an exchange basis.

It would greatly facilitate the universal use of scientific techniques in economic development if agreement on a universal language could be reached by all nations. A world language could be made existent by starting its teaching to primary school children now, when the working population of the world would be provided with a universal spoken and written means of communication in less than half a century. The most likely language to select as a world language is English, in view of the large amount of technological and scientific matter already written in this language. But even agreement on the use of a few major languages only, including English, German, Russian, Hindu, and Chinese (the important dialects of the latter three languages, of course), would considerably assist world unification. Along with the teaching of a, or one of several, common languages to all people, (the teaching of present-day national languages could continue for long enough to permit the intercommunication of individuals of different ages in each nation), should go the teaching of the important basic knowledge of humanity: viz., modern methods of food production and mining, the basic manufacturing processes, world geography, an outline of world history, basic mathematics and science, trading procedures, and the fundamental laws of psychological and social behavior. Universal education would be readily effected through the world-wide use of modern communication methods, primarily life-size television and movie showings.

The opportunity to study scientific method should be opened to all, since it is essential for the best possible rate of progress of humanity that the basic method of scientific thought be within the economic reach of every individual who could master it. Furthermore, the free and open teaching of scientific method to anyone wishing to understand the basis for world progress, will make it impossible for people to unjustly criticize scientific government. Every individual can convince himself or herself of the correctness of scientific method, and any who have not studied it will not be in a position to criticize it, since their lack of knowledge of science will mean a lack of factual support for their criticism. The percentage of new university graduates trained in scientific method is increasing steadily today.

Along with the wide teaching of science must go determined efforts to demonstrate the comparative ineffectiveness of the other (unreasoned) methods of solving problems; in particular the falseness of all forms of superstitious practices must be clearly shown. This latter task should be straightforward enough if scientists offer their reasoned approach to problems in comparison with the primitive superstitious ones.

The general aim of education in the future must be the encouragement of intelligent thought in all people, with emphasis on the necessity to require factual proof of the correctness of statements made by others, and to provide such proof for one's own statements. That is, education should be directed towards showing that each individual is capable of using his own reasoning mind to solve his basic problems in life, and that no man or woman is compelled to accept any belief held by others unless he or she satisfies him or herself of the validity of such belief by reasoned thinking. Once this attitude of criticism of unreasoned statements is attained throughout most of the world, it will have become impossible for any kind of dictatorship to gain control of people again.

Although the best future minds can be expected to enter the scientific field, because they will appreciate the essential correctness of scientific thought, it is desirable to encourage scientists in their work to discover the truth, by giving them adequate recognition and reward for this work. The world government could institute several different honorary distinctions for award to scientists achieving important advances in knowledge, which awards could be made annually. For scientists whose work leads to great economic benfits to Mankind, a system of financial rewards should be instituted as a recompense to researchers who have devoted many years to producing the means for new human wealth, usually at a financial disadvantage to themselves. In addition to encouraging young scientists to devote their lives to pure research, such a system of material rewards would discourage individuals from witholding, through patenting, their discoveries from application for Mankind's general benefit. It should be made impossible for any individual company to purchase a patent from the inventor merely in order to prevent its commercial use: the acquisition of patent rights should imply an obligatory development of the idea patented for general human use.

In this book I have covered what seems to me to be essentially all the topics which are of greatest concern to Mankind at the present epoch in our advance into the future centuries. I have endeavored to show that the most important thing for Man is his evolutionary progress, which means in essence his progress towards an ever better development of the intelligence of each individual to enable him or her to control both the environment, and him or her self, in an ever more effective way. This is the conclusion which any completely reasoning mind should reach after examining the full evidence of present-day knowledge. I have shown that we are not, and because of the nature of our minds never can be, convinced of the validity of any concept unless it is objectively proved correct to each of us. All that is so proved valid constitutes science, and therefore we can accept only scientific knowledge in our efforts to attain truth in life. I conclude that science is the most recent phase in human evolution — and that there is no possibility of any reconciliation between science and any other system of thought existing in the world today. I consider that it is possible for most individuals to accept a philosophy of life based on reason alone, and that such a philosophy is perfectly self-consistent, intellectually satisfying, and has the greatest power, to ensure the success of an individual, of any philosophy ever known to Man. This philosophy, which may be called individualism, simply asserts that for each one of us the development of our own abilities is the primary concern of life; that for the progress of Mankind the most important necessity is the recognition of the supreme significance of the individual; and that, when the long-term advance of the human species is considered, the conscious evolution of Man towards greatly increased mental capabilities is the only thing of importance. We are today able to see the path into the future of our species as a whole, and can choose to follow the scientific method of acquiring knowledge, and changing our environment to suit our needs. Let us hope that enough intelligent men and women will see the way to approach surely towards real truth in science.

as we go forward in the search for new knowledge upon and beyond the Earth.