AN HISTORICAL SURVEY OF THE RISE OF SCIENCE

In discussions concerned with its history, rigid or narrow interpretations of the term 'science' are to be avoided. The purpose of examining the history of science is, apart from mere antiquarianism, the desire to place modern science in a perspective where it may be seen in relation to other human activities, past, present and, perhaps, future; and to that purpose all from which science has grown is relevant. Mathematics may not be science, but Greek physics developed in great measure from geometry. The Egyptian goldsmith and Assyrian potter were not men of science, but chemistry developed from their labours; and between the beginnings of the use of tools and the industrial civilisation of to-day there is no moment of which we may say 'Here began Science.' In the words of Roger Bacon (*Compendia Studii.*, Cap. v, quoted by Duhem):

> *Nunquam in aliqua aetate inventa fuit aliqua scientia sed a principio mundi paulatim crevit sapientia, et adhuc non est completa in hac vita.*

But, in agreeing to allow a wide interpretation to the term Science, we are not to forget that we shall include therein several different activities, notably those of the craftsman, the observer of nature, the philosopher and ontologist, the histories of which may not always, especially in the early period, be very closely linked.

There is no direct evidence as to how men began to think systematically about things. We may conjecture one root or beginning in the rational treatment of crafts—in the work of the inventor, as distinguished from that of the pure scientist. Clearly, from the beginning of civilisation there have been those who could rise to the occasion, as men's desire to create ever greater works outran the power of their hands. Yet it is dangerous to pre-suppose an economic motive, ever upmost in our modern minds, in men to whom money was not yet known. Equally or higher must we rate the religious motive, the desire to raise great works for the gods, and the wish to understand the comings and goings of the heavenly beings and to regulate the festivals of which the primitive calendar may have consisted. Be this as it may, the corpus of knowledge concerning the practical and religious aspect of things which accumulated in the three or more millennia between the first rise and the final decline of Egypt and Assyria—to say nothing of the less-known civilisations of the East—was very considerable. The discovery of the basic materials of man's technical equipment, the metals, brick, glazed pottery and glass, tower above any similar discoveries since made; the evolution of architecture, the transformation of the crude imitations of savages to the noble inventions of the fine arts, the discovery of regularities in the complex motions of the heavenly lights, which led to the establishment of the calendar and the prediction of heavenly events, such as eclipses, the systematisation of an empirical medicine and surgery—in respect of all these the enormous and scantily documented aeons between the dawn of civilisation and the rise of the Greeks command a respect comparable with that which we accord to the other great periods of scientific thought.

But are we to speak of periods of thought at all? If we do so, we must avoid the fallacy that at any moment the world has but one habit of thought. Not only time, but the traditions of a race or place determine such habits. None of us supposes that the curtain was rung down on Egyptian and Assyrian science at the moment when Greek science made its bow. Indeed, it appears that when Greek astronomy was at its zenith, Assyrian astronomers were making observations at least as accurate as any made by the Greeks, and that no less than thirteen hundred years after the time of the Ionian philosophers the tradition of Chaldaean star-lore persisted in the schools of the Ssabaeans of Harran; and it has been argued that some of this traditional lore may have been directly transmitted to the Arabs and thence to the West. We should not visualise the rise of science as proceeding continuously nor yet by successive periods, but rather in a series of waves whose peaks are successive in time, but whose heads and tails overlap.

The first of these waves, then, is made up of the practical knowledge concerning things which was accumulated by the Egyptians and 'Chaldaeans.' Its key-note was the practical. Knowledge was not, it would seem, an end in itself, but was required to measure fields, build houses, cure the sick, settle the calendar and predict the future. It was closely connected with religion, first, because in Egypt the priests were the learned men, and secondly because the heavenly bodies were identified or associated with the gods and were therefore appropriately studied by the priest-astronomer. In this period cosmology was religious rather than scientific: conjecture as to the origin and nature of the universe would naturally refer to past tradition rather than to present observation, and we find no evidence of attempts to base on astronomical data a working model of all that was.

This impression is confirmed by the testimony of the Greeks, who without doubt derived a ground-work of natural knowledge from Egypt and Assyria. This knowledge was empirical and, probably, not very extensive, but it served to set the Greek genius to the work of rationalising and completing it. As one of the later Greeks said, the methods of the Chaldaeans and Egyptians were imperfect (in relation to astronomy) because they lacked *physiologia*—which word is the nearest Greek equivalent of natural science, and may be taken to mean a philosophy of nature and natural causes. The Egyptians and Chaldeans, from the little we know of their attitude, would seem to have thought of a universe directed by a God or gods without the intermediary of natural law: it was the Greeks that first sought for a *logos* in things, a fitting and necessary sequence of causes and effect.

It would be naive to seek a single and invariable Greek attitude to science. The observations of Hippocrates, the cosmology of Plato in the Timaeus, the mathematical physics of Archimedes, the physiology of Galen—what have they in common? One thing at least which they did not share with their predecessors or successors, namely a profound faith, nay more, a rash confidence in the power of the human intellect to discover in the universe a reasonable order and system.

As Professor John Burnet wrote, ' No sooner did an Ionian philosopher learn half-a-dozen geometrical propositions and hear that the phenomena of the heavens recur in cycles, than he set to work to look for law everywhere in nature and, with an audacity amounting to *hybris*, to construct a system of the universe.' And having made the gigantic discovery of a correspondence between the things of the mind and observed events, having discovered the connection between the ideas of geometry and the facts of astronomy, between the idea of numerical ratios and the fact of the length of the strings which gave the successive notes of the scale, the Greek philosophers did not hesitate to presume a universal correspondence between that which the human mind conceived as necessary or fitting, and that which in fact existed.

Herein lay their weakness as men of science. They did not seek from the facts a law, but conceiving as necessary certain conclusions as to the universe, they deduced from these the laws which things must evidently obey, and where the phenomena which might test these laws were hard to observe, they were little inclined to give time to their accurate observation. After pure mathematics (which is not natural science) positional Astronomy was the study in which the Greeks most excelled; it was attractive to them not only because it operated by mathematics, the realm of pure intellect, but also because it seemed to come near to satisfying their longing for the absolute and their curiosity, which would not stop short at the totality of things : to quote that noble epigram of Ptolemy :—

> *'I know that I am mortal and the creature of a day: but when I search out the massed wheeling circles of the stars, my feet no longer touch the earth, but, side by side with Zeus himself, I take my fill of ambrosia, the food of the gods.'* [1]

Lastly, astronomy gave the Greeks accurately observable phenomena to be saved, and so set bounds to the fantasies which, as we see in the Timaeus and in the works of the Pythagoreans, came readily to their ingenious and subtle brains.

In the biological sciences, concerning which man's curiosity is inextinguishable, but to which mathematics make little contribution, Greek science made no such great progress. True, a great deal was very well observed and classified by such men as Hippocrates, Aristotle, and the great anatomists of the Alexandrian school; but while Greek astronomy culminated in the Ptolemaic system, which gave a very fair explanation of the phenomena and was of high practical value for astronomical work, Greek physiology culminated in the system of the three spirits and four humours, temperaments, complexions, etc., as set out by Galen, which was of little or no value for the understanding of the body in health or disease.

Still less progress was made in physics where only the elements of theoretical statics and hydrostatics and the beginnings of optics made any progress; and in each case this was limited to the aspects of the subject which were accessible to research by geometry. It is most significant that theoretical physics did not develop into practical engineering.

Archimedes would not record his mechanical inventions, which terrified the Roman besiegers of Syracuse, thinking them unworthy of a philosopher. Even when philosophic restraint has declined, the pneumatic inventions of Ctesibius appear in the works of Heron of Alexandria and Philo of Byzantium as mechanical toys to edify worshippers or amuse the rich. It would seem that the handling of materials and instruments was not at all to the taste of classical Greece : deviation in geometry from the ascetic regimen of ruler and compass was not approved, and the laboratory would have savoured to them of the servile. Chemistry, therefore, in which the Assyrian potters and metal workers had some practical skill, made little or no progress under the Greeks.

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[1] *Greek Astronomy.* Sir Thomas L. Heath; 1932; p. lvii.

The Greek philosopher despised the mechanical arts and the apparatus of luxury: he would practice a philosophic frugality, and let the rich and their slaves see to the devices of comfort. Accordingly it was not until Roman times that the useful arts became connected with the sciences as in the period of Egyptian and Chaldaean science, and even then the prevalence of slave labour was such that the daily needs of man made small demands on the mechanical genius of the natural philosopher. From about the first century, the useful arts acquired numerous semi-scientific conveniences, aqueducts, piping, pumps, cranes: but the wave of classical science was almost spent, and men of learning and philosophic genius were already beginning to turn their eyes elsewhere.

It has been fashionable for the last two centuries to regard the decline of classical science as a falling away of knowledge and a relapse into darkness. It is quite true that in Europe there succeeded a period from *c.* 300-1100 A.D. when science was little studied, but it was not a period of abstention from science through ignorance or imbecility, but of intense concentration of the human faculties on the consequences and implications of the central event of human history; and while the gigantic research into the content of the Catholic faith was in progress, there were no eyes to spare for observation, nor powers for the elucidation of natural law. St. Augustine, deeply learned in the philosophy of Greece, speaks of this matter with utter freedom from the humbug which has been the curse of learning from the Sophists to the modern Common-Room:

> 'For great art thou, O Lord, and hast respect unto the humble, but the proud thou beholdest afar off (Ps. 137, 6). . . . nor art thou found by those that be proud, no, not though they had the curious skill to number the stars and the sand, and to quarter out the houses of the heavenly constellations and to find out the courses of the planets . . . . At these things men wonder and are astonished, that know not this Art, and they that do know it, triumph and are extolled; and out of a wicked pride, failing thereby of their light, they foresee an Eclipse of the Sun so long beforehand, but perceive not their own which they suffer in the present . . . But they knew not that way (thy word) by which thou madest these things which themselves can calculate, and the understanding out of which they do number it; or, that, of thy wisdom there is no number' (*Confessions*, Book 5, Chap. 3).

And again elsewhere:—

> 'It is likewise commonly asked of what form and figure we may believe the heavens to be, according to the Scriptures. For many contend much about those matters, which the very great prudence

of our Authors has forborne to speak of, as in no way furthering their learners in respect of a blessed life and, above all, as taking up much of that time which should be spent in holy exercises. For what is it to me whether the heavens, like a sphere, surround on all sides the earth, a mass balanced in the middle of the world, or, whether like a basin they only cover or overcast it? '

The argument at first seems irresistible. Natural science is secular knowledge. Secular knowledge is not necessary for the knowledge and service of God. No life, however long, gives more time than can be devoted to the knowledge and service of God: therefore there is no time for science.

Nor are we to think that any objection raised by St. Augustine will be lightly disposed of. The next period of science tried to answer it, the latest period of science has shelved it. We may note two features concerning this argument for the abandonment of science. First of all, it depends on the assumption that science is secular knowledge. The science of which St. Augustine is speaking is astronomy, which in some astrological form played a part in the system of the Manichees, and therefore was not only secular but a harmful usurper of the place of the true doctrine. He did not extend the same condemnation to scientific medicine, surgery and the useful arts.

Secondly, St. Augustine lived at a period when the Catholic Church was still but one of the centres of human thought: he and the faithful could afford to contract out, so to speak, and the world would go on around them. But when, in the second millennium of the Christian era, the Church became almost the sole repository of learning, then it was hers to decide whether branches of knowledge should be preserved or disappear, and another solution than that of St. Augustine and the great men of the Dark Ages had to be found.

We may picture, then, five centuries or thereabouts, when natural philosophy was not a matter of interest to the Christian world. The knowledge of the works of the ancients at no time wholly disappeared, but its volume became scanty and its treatment jejune. It has been well said that the Dark Ages were like one of those northern summer nights in which the evening twilight lingers on to meet the dawn; and when new knowledge was needed by the West there was a foundation on which to erect it, and trained minds ready to receive it.

While the Roman world was being broken down, fused with the migrant barbarians and recast in a new mould, the tradition of Greek learning remained in Byzantium and constituted a kind of prolongation of classical Greece into mediaeval Europe. Little, if any, advance in scientific matters took place there, but the treatises of

Aristotle and others survived, were read, taught, and commented upon. In the sixth and seventh centuries Greek texts were translated into Syriac and thence into Arabic. There followed the amazing phenomenon of Islamic learning. We are inclined, to-day, to attribute less of scientific discovery to the Arabs than formerly, and to regard them more as transmitters of knowledge from classical and Eastern sources than as originators of science. None the less from the eighth to the twelfth century, their standard of secular learning and manual skill greatly exceeded that of Europe in general, and this was fully realised by the Western nations. From early in the twelfth century such men as Adelard of Bath, Gerard of Cremona, Michael Scot, Hermann the German, began to tap the Greek learning and science stored in Arabic versions of classical authors which had not previously been accessible to the West. By the early thirteenth century, Aristotle, Ptolemy, etc., together with the acute commentaries and original works of such men as Averroes, Avicenna, Alhazen, Rhazes, Alkindi, were available in Latin versions. In one century the Western world grew more in mental stature than it had in the five which preceded it. The assimilation of Catholic doctrine with Greek learning and the creation of something new and integral from both was the task of the thirteenth century. The most pressing need for such assimilation was in the realm of metaphysics, ethics, and psychology; it may be questioned whether the world was then ready for Greek science, which was studied more because it was a part of the Aristotelian philosophic system than because the thirteenth century had need of it. It was, however, no longer felt that time spent on secular learning was time wasted, because there was no longer any secular learning. 'That the power of philosophy is not foreign to the Wisdom of God, but included in it, must be made manifest,' says Roger Bacon (*Opus Majus*, Par. II, Cap. 3). For science, St. Albert, Roger Bacon and St. Thomas Aquinas stand out as the figures of the age; the first a universal genius and true man of science, the second a prophet of science born out of time and foreshadowing that which the world was not to see for three centuries or more, the third the creator of a gigantic scheme of thought in which alone, perhaps, science finds its due place. St. Albert and Roger Bacon were truly men of science. They took the text books of the age—Aristotle, Alhazen, Euclid, etc.—as their ground-work, but they used their own observation and made experiments. St. Albert speaks of the need for decision by experiment, while Roger Bacon attains to the height of conceiving and abstracting from experimental practice the idea of a scientific method. Indeed, an age of experimental science seemed to be dawning with Peter

Peregrine, the physicist, the numerous alchemists, Leonard of Pisa the mathematician, Mondino the anatomist. The promise was, however, not fulfilled, and the new growth lignified into the conventional Aristotelian teaching about natural philosophy which persisted without much change till the seventeenth century.

Here then is our third wave of scientific culture rising from Byzantium, climbing through Islam, culminating in the thirteenth century and declining both in Islam and the West to a gradual disappearance at the close of the seventeenth century. Meanwhile, the fourth wave was gathering in a curious and secret fashion. While Aristotle was ascendant, Plato was never wholly forgotten, and, as I read the signs, the minds of a select and discreet few laid hold on that ancient unifier of nature, the world-soul of the Timaeus, which a scholiast describes as 'a creative fire found around the middle and centre of the earth which heats the earth and animates it, and maintains order at its surface' (Brandis, *Scholia in Aristotelem*, 504-5).

This notion of the central animating power, the 'certain pure matter' of the alchemist, the *quinta essentia*, which perfected the metals in the mines, was a source of life to all that lived, and constituted the animal spirits which linked the soul to the body, was a notion central to alchemy, served to rationalise astrology, but was not at all easy to fit into the accepted Aristotelian cosmology. It remained a secret doctrine, found in alchemical works, and hinted at in various fashions. Marsilio Ficino in the later fifteenth century seems to have been a centre of such teaching, and fifteenth-century Italy seems to have radiated unorthodox natural philosophy. Heliocentric astronomy was a subject of discussion, the 'central fire' of the Pythagoreans being mistakenly assimilated to the sun; and it seems probable that Copernicus during his stay in Italy received the germ of the theory which he was to substantiate with the aid of the ever more accurate astronomical observations which had become available. Throughout the late fifteenth and most of the sixteenth century there was a curious atmosphere of secrecy surrounding the new science, which was being learned both from newly available Greek texts and by experiment. Notice the curious symbolism of the scientific instruments in Holbein's *Ambassadors*, Dürer's *Malinconia*, Giorgione's *Three Philosophers*: note the secrecy of Leonardo da Vinci: note the combination of the magical and scientific in the works of such men as Cornelius Agrippa, Paracelsus, Gianbattista della Porta, John Dee, van Helmont, Kenelm Digby, and many another. These men did not distinguish what we call magic from what we call science; *natural magic*, of which they spoke with commendation, to them meant any manipulation of what they believed to be nature's forces, among which the supposed operation of influences and sympathies seemed to be included no less appropriately than those attractions (as of magnet and iron, or amber and straw), which we call physical. Space forbids further discussion of the re-emergence of natural philosophy in the sixteenth century: let us pass at once to the portentous emergence of modern science. Modern science, which was a vigorous child at the end of the seventeenth century and an inchoate embryo at its beginning, is distinguished from the natural philosophy of the years which preceded that century, by its limitation to such aspects of matter as are definable at best in terms of length, mass and time, or, where this is impossible, in terms of such sense-data as men in practice are found to agree upon closely. The limitation applies both to the data it accepts, the explanations it is prepared to adopt, and the modes of causality it refers to in its predictions. With modern science come the notions of scientific truth and open publication, which amount to a recognition that a free and complete knowledge of facts accelerates the advance of science, and that no limitations are to be placed upon the classes who are to have access to the knowledge and power which science gives. Finally, the increase of man's power and wealth through industry comes to be recognised and avowed as a primary purpose of science.

The scientific method was revolutionary in its separation of scientific knowledge from philosophy. The natural philosopher, Plato or St. Albert, said: 'I will consider all that is.' The seventeenth-century man of science said: 'I recognise that there is much that natural science cannot study. I set that aside to be studied by the methods of philosophy and religion, and I will study the remainder by the aid of my experimental philosophy.' Thus Newton's cosmic system is based on mutual attractions which he does not consider it his part to account for. Ancient science sought to explain; modern science merely to describe in terms of a few simple entities, themselves inexplicable or unexplained.

The result, wholly unforeseen, of this division of knowledge, is that scientific description, which is cumulative, has grown out of all proportion to philosophic explanation, which is not. Natural science, moreover, has come to be of immediate everyday importance to everybody, and its results, if not its methods and technique, are forced on the notice of every man living. In the last century when this first became apparent, it led to a huge increase in the fallacy, often tacitly assumed and sometimes publicly professed, that outside the field of science there is nothing but illusion and fancy; and this to-day is the belief of a great part of those who live in communities permeated by the ideas and contrivances of science.

No single man can be regarded as the founder of modern science; various aspects of it are foreshadowed in the work of such men as Vesalius, Copernicus, Paracelsus, Ambroise Paré, Simon Stevin, William Gilbert and many others; but two great men, Galileo Galilei and Francis Bacon, stand out as those whom their contemporaries recognised as marking the threshold of a new mansion of human achievement. By Galileo the scientific method was first practically realised in its entirety; by Bacon it was first enunciated as a system of knowledge.

Galileo became world-famous through his astronomical discoveries, which might have been made by any natural philosopher who had the fortune to hear of the idea of a telescope and the high degree of practical skill needed to construct an efficient instrument. The importance of his demonstration that the region above the moon was not essentially different from that below cannot be over-rated, yet from the point of view of the development of modern science, his rejection of Aristotelian mechanics, his quantitative experimental investigations, and resultant mathematical treatment of statics and dynamics take a yet higher place. In these unexampled researches he presents us with a picture of the man of science in action. His limitation of the data of science to observation and experiment and his rejection of authority are sufficiently shown in his treatment of falling bodies and other problems of physics, without entering upon the unhappy controversy concerning Copernican astronomy, in which neither the philosopher nor the Church appeared at their best. Yet the controversy was significant, more so perhaps than either side was aware. For behind the fireworks of polemic and the special pleading, the citations of authority and the judicial decisions, lay two profound judgments, the judgment of Galileo that without complete freedom from authoritative decisions on scientific conclusions, modern science could not be created, and the judgment of the Church that the separation of science from the integral corpus of knowledge was a schism of the profoundest consequence.

The line from Galileo to modern science is straight and clear through the workers of the Accademia del Cimento, imbued with his spirit, to the Royal Society and the other Academies. Yet doubtless the foundation members of the Royal Society would have claimed as their progenitor not Galileo, but Francis Bacon, 'the man who rang the bell that called the wits together.' It has been fashionable to decry Bacon. He was no scientist, it is true; and many of the experiments he suggested and performed are evidently the products of a man who had spent more time at court than in the laboratory or workshop. His metaphysical attainments are not to be rated very high, but his statement of the essentials of the scientific method was forcible, and, considering that he wrote before experimental science had been proved in practice, remarkably sound; it was, moreover, perfectly timed to draw men to the new knowledge. Bacon's works enunciated a programme and a method of study, but his works could not supply the knowledge of laboratory technique and the manner of setting about a practical scientific problem, nor could they reveal the power of mathematics in interpreting the results of experiment. This may be the reason why science hung fire for a decade or two after Bacon's publications, and I would date the end of the preface and the beginning of the text of modern science about 1650, when Baconian theory, Italian technique, and Cartesian mechanistic natural philosophy seemed to present men with the means of elucidating all observable things.

Since that time the rise of pure science has been rapid, ceaseless, and ever accelerating. Through the late seventeenth and eighteenth century we watch a continuous perfection of laboratory technique, the working out of more powerful methods of mathematical theory, the reduction of more and more departments of knowledge to the state of organised and rational sciences. The advance of science exceeded all hope; so much so that the sanguine began to think that the method which had accomplished so much was capable of doing all that man could ask, and of elucidating the problems to which, hitherto, revelation had supplied the only answer. To pursue the history of rationalism, positivism, and materialism into the present age is not a matter for this historical survey, nor is this the place to discuss the controversies of religion and science which shook the nineteenth century and are still living and anxious problems to many. Suffice it to say that many have not yet decided for themselves what is the province and what the powers of science, while many again have decided superficially and unphilosophically that science is our only light.

I am not one of those who see in economic necessity the cause of scientific progress. The great discoveries of science, when first made, have for the most part little bearing on practical affairs, neither arising immediately from them, nor being applicable to them until a certain amount of subsidiary research has been done. I can conceive very well of a state of society in which pure science coud flourish and applied science be largely neglected, but such a socity we have not seen and are not likely to see, in our time at any rate.

The notion of the application of science to the needs of man is an ancient one. Roger Bacon was alive to it, urging the necessity for the study of science so that the Church festivals might be properly regulated, geographical positions mapped, and astrological influences properly computed. Leonardo da Vinci's notebooks are full of practically useful mechanical contrivances and throughout the sixteenth-century 'engines'—water-wheels, pumps, saw-mills, combination of mechanical powers, devices for raising ships, etc.—attracted much attention. As mining and smelting became more extensive industries, pumping-machinery had to be improved : the need to supply water to the growing towns created the same want. In the period of 'books of secrets' there was a feeling that a knowledge of nature's ways ought to be useful, and at the beginning of the seventeenth century Francis Bacon crystallised these diffuse aspirations in the notion of the *imperium hominis*, the rule of man over nature. Man, was to improve his lot by the use of natural science, urged Bacon : but the course this improvement was to take was mercifully hidden from him, and while mechanical invention and the use of power created a very different world from that which he foresaw, the great works that he expected science to accomplish were not in fact realised before the end of the nineteenth century.

The application of science to crafts and industries made little stir before the late eighteenth century. Some ingenious devices such as the stocking-frame came into use in the early seventeenth century, and from this time on there was a steady progress in craftsmanship, largely to be attributed to the skill required of the clockmaker, instrument maker, locksmith and gunsmith. Foreign trade was bringing a demand for larger quantities of textile goods than the limited supply of skilled craftsmen could turn out. The slowest of the textile processes was spinning, so naturally there were efforts to produce spinning machinery, and in the latter part of the eighteenth century the momentous step was taken of operating a large number of spinning machines by a single water-wheel, and the factory system was born. Meanwhile, the steam-engine was being perfected. The Marquis of Worcester seems fairly certainly to have had some kind of steam-pump in the mid-seventeenth century : before the end of the century Savery's engine had been devised. Newcomen's beam-engine came at the beginning of the eighteenth century, and improvement in such engines continued until the genius of James Watt turned the steam pumping engine into a rotary engine capable of becoming the prime mover of a factory. From 1782, the year of the first rotary Watt engine, industrial civilisation began. The textile trades were mechanised, and the power of exploiting the labour of the politically helpless was horribly augmented. The subsequent course of applied science is well enough known. The years 1825 to 1850 saw the creation of the railroads. The years 1860 to 1880 gave us sanitation, a clean water supply, antiseptic surgery and preventive medicine. Between 1890 and 1905 came electric supply, mechanical road transport, and the re-housing of the slum-dwellers in the outer belt of the towns. From 1905 to 1930 was the great age of the internal combustion engine with its further mobilising of the people: from 1920 the period of mechanised amusements; the years from 1930 to the present day have been the era of preparations for and realisation of mechanised war.

I have not touched on a tithe of the discoveries which have altered people's lives, but I shall conclude by presenting a problem, which serves to summarise the application of science to daily life, and at the same time to ask a question. Let us divide the last 150 years, 1790-1940, into three half-centuries, and let us consider the first-class practical discoveries made in each of them.

Here is a list of the discoveries and inventions which I have chosen (somewhat arbitrarily, I confess) as those which are of the first rank of importance to the man-in-the-street. (I speak only of applied science and assign each discovery to the period of its first coming into use, not of its first invention.)

1792-1842. Steam power in factories. Railways. Steam-ships. Gas. Matches. The stethoscope. Vaccination. Iron pipes. (8 discoveries.)

1842-1892. Dynamo, and electric motor. Internal-combustion engine. Bicycle. Iron ships. Telephone. Telegraph. Ocean cable. Photography. Sanitation. Chloroform. Aseptic surgery. Control of cholera and typhoid. Clinical thermometer. Canned food. Disinfectants. Synthetic drugs and dyes. Photography. Rubber. Galvanised iron. Cheap steel. High explosives. The breech-loading rifle. Armour-plate. Torpedo. (26 discoveries.)

1892-1942. Electric-supply grid. Use of electricity in factories. Electric trams. Electrification of rail. Electric lighting and heating. Automobile in all forms. Motor boat and ship. Dirigible airship. Aeroplane. Glider. Wireless telegraphy, wireless telephony, broadcasting, television, radiolocation, cinema, sound-film, robot-machinery generally. X-rays. Ultra-violet and infra-red radiation. Rayon. Plastics, Aluminium. Ferroconcrete. Synthetic fertilisers. Synthetic drugs. Synthetic rubber. Synthetic oil. Chemotherapy. Radium. Vitamins. Antitoxins. Vaccine therapy. Control of tropical disease. Machine-guns. Poison gas. Submarines. Tanks, and an array of other weapons. (42 discoveries.)

Are we entitled to extrapolate the curve showing number of discoveries against time, and to conclude that the next fifty years will provide sixty first-class discoveries seriously affecting human lives, and that some ten of these are likely to be death-dealing atrocities? Or can we expect a change in conditions which will stem or regulate this flood—perhaps a new economic system, as of Soviet Russia; perhaps a realisation that the seventy or so first class discoveries of science have not made the world of 1940 so greatly superior to that of 1790? Science has operated hitherto without any control other than the pay of the capitalist and the choice of the research worker. Is it not perhaps our part to consider whether and, if so, how research may be directed; or, alternatively, whether the exploitation of its results should not be restrained in such fashion that our civilisation may be saved from destruction. And indeed we may come to wonder whether our industrialised civilisation is worth saving and whether the world of the future may regret our downfall no more than we regret that of the Roman Empire.

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SCIENCE AND REASON

Faced with the great human crisis of our times, it is only natural that the scientist should feel that he has his contribution to make towards a solution of our one great problem—to secure the survival of the things that are good. The scientist has, moreover, a certain confidence that his contribution is important, perhaps even decisive, and certainly indispensable. He is confirmed in this view by the reflection that a large proportion of the world's troubles may be traced to a desertion of scientific ideals, a neglect of scientific principles and the substitution of comfortable and muddle-headed *illusions* for the *facts* which are the scientist's stock-in-trade.

Scientists are now beginning to feel that they have something to give beyond their material contribution, something in the realm of values, of ideals, of human harmony and ordered social progress. This contribution has reference both to the war effort and to reconstruction—to the armed struggle in which we are now engaged, and