



Photograph taken by an undergraduate during a lecture "at the risk of his life"
(J Maynard Smith)

Daedalus or Science and the Future

As I sit down to write these pages I can see before me two scenes from my experience of the late war. The first is a glimpse of a forgotten battle of 1915. It has a curious suggestion of a rather bad cinema film. Through a blur of dust and fumes there appear, quite suddenly, great black and yellow masses of smoke which seem to be tearing up the surface of the earth and disintegrating the works of man with an almost visible hatred. These form the chief parts of the picture, but some where in the middle distance one can see a few irrelevant looking human figures, and soon there are fewer. It is hard to believe that these are the protagonists in the battle. One would rather choose those huge substantive oily black masses which are so much more conspicuous, and suppose that the men are in reality their servants, and playing an inglorious, subordinate, and fatal part in the combat. It is all possible, after all, that this view is correct. Had I been privileged to watch a battle three years later, the general aspect would have been very similar, but there would have been fewer men and more shell-bursts. There would probably, however, have been one very significant addition. The men would have been running, with mad terror in their eyes, from gigantic steel slugs which were deliberately,

" Black is his robe from top to toe,
His flesh is white and warm below,
All through his silent veins flow free' Hunger and
thirst and ventry,
But in his eyes a still small flame
Like the first cell from which he came
Burns round and luminous, as he rides
Singing my song of deicides."

1 Embden, Grafe, and Schmitz. Zeitschrift
für physiologische Chemie, Vol. 113, p. 67, 1921.

2 The Hindus have recognized the special and
physiological relation of man to the cow by making the
latter animal holy. A good Hindu would no more kill a
cow than his foster-mother. But the holiness of
the cow has unfortunately extended to all its products, and
the extensive use of cowdung in Indian religious
ceremonies is disgusting to the average European. The
latter however. is insensitive to the equally loathsome
injunctions of the Catholic Church with regard to human
marriage. It would perhaps be better if both marriage and
milking could be secularized.

ousting him from the mastery of this planet? Is the
machine-minder engaged on repetition-work the goal and
ideal to which humanity is tending? Perhaps a survey of
the present trend of science may throw some light on
these questions. But first we may consider for a moment,
the question of whether there is any hope of stopping the
progress of scientific research. It is after all a very recent
form of human activity, and a sufficiently universal
protest of mankind would be able to arrest it even now. In
the middle ages public opinion made it so dangerous as to
be practically impossible, and I am inclined to suspect
that Mr. Chesterton, for example, would not be averse to a
repetition of this state of things. The late M. Joseph
Reinach, an able and not wholly illiberal thinker, publicly
advocated it. I think, however, that so long as our present
economic and national systems continue, scientific
research doubt has little to fear. Capitalism, though it may
not always give the scientific worker a living wage, will
always protect him, as being one of the which produce
golden eggs for its table. And competitive
nationalism, even if war is wholly or largely prevented,
will hardly forego the national advantages accruing from
scientific research. If we look at the other most probable
alternative the prospect is little more hopeful. In this
country the labour party alone among political

bad which were formerly good. Our increased knowledge of hygiene has transformed resignation and inaction in face of epidemic disease from a religious virtue to a justly punishable offence. We have improved our armaments, and patriotism, which was once a flame upon the altar, has become a world-devouring conflagration. The time has gone by when a Huxley could believe that while science might indeed remould traditional mythology, traditional morals were impregnable and sacrosanct to it. We must learn not to take traditional morals too seriously. And it is just because even the least dogmatic of religions tends to associate itself with some kind of unalterable moral tradition, that there can be no truce between science and religion. There does not seem to be any particular reason why a religion should not arise with an ethic as fluid as Hindu mythology, but it has not yet arisen. Christianity has probably the most flexible morals of any religion, because Jesus left no code of law behind him like Moses or Muhammad, and his moral precepts are so different from those of ordinary life that no society has ever made any serious attempt to carry them out, such as was possible in the case of Israel and Islam. But every Christian church has tried to impose a code of morals of some kind for which it has claimed divine sanction. As these codes have always been

years there was a hansom-cab in a museum, and now that romantic but tardy as vehicle is a memory like the trireme, is the velocipede, and the 1907 Voisin biplane. I do not suggest that Mr. Chesterton be dragged -a heavier Hector -behind the last hansom cab, but I do contend that, in so far as he claims to be a prophet rather than the voice of one crying in the wilderness, he may be regarded as negligible for the purpose of our discussion. I shall try shortly to show how far from complete are any branches of science at the present time. But first a word on Mr. H. G. Wells might not be out of place. The very mention of the future suggests him. There are two points which I wish to make about Mr. Wells. In the first place, considered as a serious prophet, as opposed to a fantastic romancer, he is singularly modest. In 1902, for example, in a book called "Anticipations," he gave it as his personal opinion that by 1950 there would be heavier than air flying machines capable of practical use in war. That, said he, was his own view, though he was well aware that it would excite considerable ridicule. *I propose in this paper to make no prophecies rasher than the above.* The second and more important point is that he is a generation behind the time. When his scientific ideas were formed, flying and radiotelegraphy, for example, were scientific problems, and the centre of scientific interest still that lay

intolerable in conjunction with our present system of relations between classes and sexes. Moral progress is so difficult that I think any developments are to be welcomed which present it as the naked alternative to destruction, no matter how horrible may be the stimulus which is necessary before man will take the moral step in question. To sum up then, Science is as yet in its infancy, and we can foretell little of the future save that the thing that has not been is the thing that shall be; that no beliefs, no values, no institutions are safe. So far from being an isolated phenomenon the late war is only an example of the disruptive results that we may constantly expect from the progress of science. The future will be no primrose path. It will have its own problems. Some will be the secular problems of the past, giant flowers of evil blossoming at last to their own destruction. Others will be wholly new. Whether in the end man will survive his accessions of power we cannot tell. But the problem is no new one. It is the old paradox of freedom re-enacted with mankind for actor and the earth for stage. To those who believe in the divinity of that part of man which aspires after knowledge for its own sake, who are able, in the words of Boethius:

experimental proof or disproof of such deductions is difficult, and-if the late war may be regarded as an experimental disproof of certain of Hegel's political tenets-costly and unsatisfactory. Einstein, so far from deducing a new decalogue, has contented himself with deducing the consequences to space and time themselves of their ideality. These are mostly too small to be measurable, but some, such as the deflection of light by the sun's gravitational field, are susceptible of verification, and have been verified. The majority of scientific men are now being constrained by the evidence of these experiments to adopt a very extreme form of Kantian idealism. The Kantian *Ding-an-sich* is an eternal four-dimensional manifold, which we perceive as space and time, but what we regard as space and what as time is more or less fortuitous. It is perhaps interesting to speculate on the practical consequences of Einstein's discovery. I do not doubt that he will be believed. A prophet who can give signs in the heavens is always believed. No one ever seriously questioned Newton's theory after the return of Halley's comet. Einstein has told us that space, time, and matter are shadows of the fifth dimension, and the heavens have declared his glory. In consequence Kantian idealism will become the basal working hypothesis of the physicist and finally of all the

urged that they are only fit to be placed in the hands of a being who has learned to control himself, and that man armed with science is like a baby with a box of matches. The answer to this contention may, I think, be found in the daily papers. For scores of centuries idealists had urged that wars must cease and all As long as any other alternative was possible it was persisted in. The events of the last nine years constituted a reductio ad absurdum of war, but when we ask who was responsible for this we shall find that it was not the visionaries but men like Black, Kekule, and Langley, who enlarged man's power over nature until he was forced by the inexorable logic of facts to form the nucleus of an international government. We have already reacted against the frame of mind that engendered the league of nations, but we have not reacted at all completely. The league exists and is working, and in every country on earth there are many people, and ordinary normal people, who favour the idea in one form or another of a world state. I do not suggest that a world-state will arise from the present league--or for the matter of that from the third international. I merely observe that there is a widespread and organized desire for such an institution, and several possible nuclei for it. It may take another world-war or two to convert the majority. The prospect of the next

Bergsonian activism. I do not for one moment suggest that this or any other metaphysical system has any claims whatever to finality. Meanwhile we are in for a few centuries during which many practical activities will probably be conducted on a basis, not of materialism, but of Kantian idealism. How will this affect our manners, morals and politics? Frankly I do not know, though I think the effect will be as great as that of Newton's work, which created most of the intellectual forces of the 18th century. The Condorcets, Bentham's, and Marx's of the future will I think be as ruthlessly critical of the metaphysics and ethics of their times as were their predecessors, but not quite so sure of their own; they will lack a certain heaviness of touch which we may note in Utilitarianism and Socialism. They will recognise that perhaps in ethics as in physics, there are so to speak fourth and fifth dimensions that show themselves by effects which, like the perturbations of the planet Mercury, are hard to detect even in one generation, but yet perhaps in the course of ages are quite as important as the three-dimensional phenomena. If the quantum hypothesis is generally adopted even more radical alterations in our thinking will be necessary. But I feel it premature even to suggest their direction in the present unsatisfactory state of quantum mechanics. It may be that

and civilisations, doubters, disintegrators, deicides. In the past they have been, in general, men like Voltaire, Bentham, Thales, Marx, and very possibly the divine Julius, but I think that Darwin furnishes an example of the same relentlessness of reason in the field of science. I suspect that as it becomes clear that at present reason not only has a freer play in science than elsewhere, but can produce as great effects on the world through science as through politics, philosophy, or literature, there will be more Darwins. Such men are interested primarily in truth as such, but they can hardly be quite uninterested in what will happen when they throw down their dragon's teeth into the world. I do not say that biologists as a rule try to imagine in any detail the future applications of their science. The central problems of life for them may be the relationship between the echinoderms and brachiopods, and the attempt to live on their salaries. They do not see themselves as sinister and revolutionary figures. They have no time to dream. But I suspect that more of them dream than I. would care to confess it. I have given above a very small selection from my dreams. Perhaps they are bad dreams. It is of course almost hopeless to attempt any very exact prophecies as to how in detail scientific knowledge is going to revolutionize human life, but I believe that it will continue to do so, and even more

tending to bring mankind more and more together, to render life more and more complex, artificial, and rich in possibilities -to increase indefinitely man's powers for good and evil. But there are two prerequisites for all progress of this kind, namely continuous supplies of human and mechanical power. As industries become more and more closely interwoven, so that a dislocation of anyone will paralyse a dozen others (and that is will the position towards which we are rapidly moving), the ideal of the leaders of industry, under no matter the what economic system, will be directed less and less to the indefinite increase of production in the intervals between such dislocations, and more and more to stable and regular production, even at the cost of reduction of profits and output while the industry is proceeding normally. It is quite possible that capitalism itself may demand that the control of certain key industries be handed over completely to the workers in those industries, simply in order to reduce the number of sporadic strikes in them. And as industrial progress continues an ever larger number- perhaps the majority -of industries will become key industries. The solution may be entirely different -we may well see a return to feudalism. But the probability is that the problem will be solved. This view may seem optimistic, but it is more likely than the alternative thesis

has arrived at certain generalizations of a rather abstract and philosophic character, but these are still to some extent matters of controversy. And though a vast number of most important empirical facts are known, only a few great generalizations from them-such as the existence of the subconscious mind- have yet been made. But anyone who has seen even a single example of the power of hypnotism and suggestion must realise that the face of the world and the possibilities of existence will be totally altered when we can control their effects and standardize their application, as has been possible, for example, with drugs which were once regarded as equally magical. Infinitely greater, of course, would be the results of the opening up of systematic communication with spiritual beings in another world, which is claimed as a scientific possibility. Spiritualism is already Christianity's most formidable enemy, and we have no data which allows us to estimate the probable effect on man of a religion whose dogmas are a matter of experiment, whose mysteries are prosaic as electric lighting, whose ethics are based on the observed results in the next world of a good or bad life in this. Yet that is the prospect before us if spiritualism obtains the scientific verification which it is now demanding, not perhaps with great success. I have only been able, in the time at my disposal, to traverse a very

sources of power, the wind and the sunlight. The problem is simply one of storing their energy in a form as convenient as coal or petrol. If a windmill in one's back garden could produce a hundredweight of coal daily (and it can produce its equivalent in energy), our coalmines would shut will down to-morrow. Even to-morrow a cheap, foolproof, and durable storage battery may be invented, which will enable us to transform the intermittent energy of the wind into continuous electric power. Personally, I think that four hundred years hence the power question in England may be solved somewhat as follows: The country will be covered with rows of metallic windmills working electric motors which in their turn supply current at a very high voltage to great electric mains. At suitable distances, there will be great power stations where during windy weather the surplus power will be used for the electrolytic decomposition of water into oxygen and hydrogen. These gases will be liquefied, and stored in vacuum jacketed reservoirs, probably sunk in the ground. If these reservoirs are sufficiently large, the loss of liquid due to leakage inwards of heat will not be great; thus the proportion evaporating daily from a reservoir 100 yards square by 60 feet deep would not be 1/1000 of that lost from a tank measuring two feet each way. In times of calm, the gases will be recombined in

example, to control our passions by some more direct method than fasting and flagellation, to stimulate our imagination by some reagent with less after-effects than alcohol, to deal with perverted instincts by physiology rather than prison. Conversely there will inevitably arise possibilities of new vices similar to but even more profound than those opened up by the pharmacological discoveries of the 19th century. The recent history of medicine is as follows. Until about 1870 medicine was largely founded on physiology, or, as the Scotch called it "Institutes of J medicine ". Disease was looked at from the point of view of the patient, as injuries still are. Pasteur's discovery of the nature of infectious disease transformed the whole outlook, and made it possible to abolish one group of diseases. But it also diverted scientific medicine from its former path, and it is probable that, were bacteria unknown, though many more people would die of sepsis and typhoid, we should be better able to cope with kidney disease and cancer. Certain diseases such as cancer are probably not due to specific organisms, whilst others such as phthisis are due to forms which are fairly harmless to the average person, but attack others for unknown reasons. We are not likely to deal with them effectually on Pasteur's lines, we must divert our view from the micro-organism to the patient. Where the doctor cannot

shortly, I do not much believe in the commercial possibility of induced radio-activity. Before I turn to the principal part of my subject I should like to consider very briefly the influence on art and literature of our gradual conquest of space and time. I think that the blame for the decay of certain arts rests primarily on the defective education of the artists. An artist must understand his subject matter. At present not a single competent poet and very few painters and etchers outside the Glasgow School understand industrial life, and I believe that there is only one architect of any real originality who understands the possibilities of ferroconcrete. I do not know his name, but he produced in Soissons before the war a market-place with the dignity and daring of an ancient Egyptian temple. If I knew that he had been entrusted with the rebuilding of Soissons, I could not regret its destruction. Now if we want poets to interpret physical science as Milton and Shelley did (Shelley and Keats were the last English poets who were at all up-to-date in their chemical knowledge), we must see that our possible poets are instructed, as their masters were, in science and economics. I am absolutely convinced that science is vastly more stimulating to the imagination than are the classics, but the products of this stimulus do not normally see the light because scientific men are as a class devoid of any perception of literary

becoming an ectogenetic mother of the next generation involves an operation which is somewhat unpleasant, though now no longer disfiguring or dangerous, and never physiologically injurious, and is therefore an honour but by no means a pleasure. Had this not been the case, it is perfectly possible that popular opposition would have proved too strong for the selectionist movement. As it was the opposition was very fierce, and characteristically enough this country only adopted its present rather stringent standard of selection a generation later than Germany, though it is now perhaps more advanced than any other country in this respect. The advantages of thorough-going selection, however, proved to be enormous. The question of the ideal sex ratio is still a matter of violent discussion, but the modern reaction towards equality is certainly strong." Our essayist would then perhaps go on to discuss some far more radical advances made about 1990, but I have only quoted his account of the earlier applications of biology. The second appears to me to be neither impossible nor improbable, but it has those features which we saw above to be characteristic of biological inventions. If reproduction is once completely separated from sexual love mankind will be free in an altogether new sense. At present the national character is changing slowly according to quite unknown

substance the most important being metals. But there were explosives, dyes, and drugs before chemistry was a science, and its progress along present lines will mainly alter life in a quantitative manner. Perhaps the biggest problems before it in metallurgy are the utilization of low-grade iron ores, and the production of aluminium from clay, which contains up to 24% of that metal. I do not think that even when this is accomplished aluminium will oust iron and steel as they ousted bronze and flint, but its alloys will certainly take the second, and possibly the first place as industrial metals. There is just a hope, though I fear little more, that a large-scale production of perfume may form the basis of a re-education of our rather rudimentary sense of smell, but the most interesting possibilities of chemical invention are very clearly in biological chemistry, and for the following reasons. Desirable substances fall on the whole into two classes. The first are desirable on account of their physical or chemical properties, for example iron, wood or glass, which we use as a part of systems such as fires, houses, or razors, which procure us certain benefits. The second are desirable on account of their physiological properties. Such substances include foods, drinks, tobacco, and drugs. Colours and scents occupy an intermediate position. The value of this second class of substances rests

embryo rabbits from one female to another, in 1925 Haldane had grown embryonic rats in serum for ten days, but had failed to carry the process to its conclusion, and it was not till 1940 that Clark succeeded with the pig using Kehlmann's solution as medium. Dupont and Schwarz obtained a fresh ovary from a woman who was the victim of an aeroplane accident, and kept it living in their medium for five years. They obtained several eggs from it and fertilized them successfully, but the problem of the nutrition and support of the embryo was more difficult, and was only solved in the fourth year. Now that the technique is fully developed, we can take an ovary from a woman, and keep it growing in a suitable fluid for as long as twenty years, producing a fresh ovum each month, of which 90 per cent can be fertilized, and the embryos grown successfully for nine months, and then brought out into the air. Schwarz never got such good results, but the news of his first success caused an unprecedented sensation throughout the entire world, for the birthrate was already less than the deathrate in most civilised countries. France was the first country to adopt ectogenesis officially, and by 1968 was producing 60,000 children annually by this method. In most countries the opposition was far stronger, and was intensified by the Papal Bull *II Nunquam prius audito*, and the similar fetwa

for nine months on end with very great effect on their output. It has no after-effects like those of alcohol, and one cannot take a serious overdose as it merely acts as a purgative. (They gave certain Stoss-truppen too much!) Thousands of people in Germany take it habitually. It is possible that it may become as normal a beverage as coffee or tea. It costs 1/9 per pound, or 1/3d. per dose. The vast majority of chemical substances with physiological properties are unsuited for daily use like castor oil, or dangerous like morphine; probably none are without bad effects in certain cases. Those which are susceptible of daily use are of the utmost social importance. Tobacco has slight but definite effects on the character. Coffee-houses in London in the seventeenth and eighteenth centuries and cafes in modern Europe were and are civilizing influences of incalculable value. But these substances are profoundly obnoxious to a certain type of mind. It would perhaps be fantastic to suggest that Sir Walter Raleigh owed his death in part to his sovereign's objection to tobacco. But if he is not its proto-martyr it is at least probable that more men have died for tobacco smoking at the hands of Sikhs, Senussis, and Wahabis, whose religions forbid this practice, than died under the Roman empire for professing Christianity. Should it ever be generally realised that temperance is a

foreseen the practical bearing of such results. As a matter of fact it was not until 1940 that Selkovski invented the purple alga *Porphyrococcus fixator* which was to have so great an effect on the world's history. In the 50 years before this date the world's average wheat yield per hectar had been approximately doubled, partly by the application of various chemical manures, but most of all by the results of systematic crossing work with different races; there was however little prospect of further advance on any of these lines. *Porphyrococcus* is an enormously efficient nitrogen-fixer and will grow in almost any climate where there are water and traces of potash and phosphates in the soil, obtaining its nitrogen from the air. It has about the effect in four days that a crop of vetches would have had in a year. It could not, of course have been produced in the course of nature, as its immediate ancestors would only grow in artificial media and could not have survived outside a laboratory. Wherever nitrogen was the principal limiting factor to plant growth it doubled the yield of wheat, and quadrupled the value of grass land for grazing purposes. The enormous fall in food prices and the ruin of purely agricultural states was of course one of the chief causes of the disastrous events of 1943 and 1944. The food glut was also greatly accentuated when in 1942 the Q strain of *Porphyrococcus*

satisfactory diet can be produced in this way on a commercial scale. This will mean that agriculture will become a luxury, and that mankind will be completely urbanized. Personally I do not regret the probable disappearance of the agricultural labourer in favour of the factory worker, who seems to me a higher type of person from most points of view. Human progress in historical time has been the progress of cities dragging a reluctant countryside in their wake. Synthetic food will substitute the flower garden and the factory for the dunghill and the slaughterhouse, and make the city at last self-sufficient.

*There's many a strong farmer whose heart
would break in two
If he could see the townland that we
are riding to.
Boughs have their fruit and blossom at
all times of the year,
Rivers are running over with red beer
and brown beer,
An old man plays the bagpipes in a
golden and silver wood,
Queens, their eyes blue like the ice,
are dancing in a crowd.*

generally incompetent for ten years before his death. His son succeeds him at the age of fifty or so, by which time he may be a fairly competent colonel or stockbroker, but cannot hope to learn the art of managing an estate. In consequence he either hands it over to an agent who is deprived of initiative and often corrupt, or runs it unscientifically, gets a low return, and ascribes to Bolshevism what he should really lay at the door of vaccination. But to return, if I may use the expression, to the future, I am going to suggest a few obvious developments which seem probable in the present state of biological science, without assuming any great new generalizations of the type of Darwinism. I have the very best precedents for introducing a myth at this point, so perhaps I may be excused if I reproduce some extracts from an essay on the influence of biology on history during the 20th century which will (it is hoped) be read by a rather stupid undergraduate member of this university to his supervisor during his first term 150 years hence. As early as the first decade of the twentieth century we find a conscious attempt at the application of biology to politics in the so-called eugenic movement. A number of earnest persons, having discovered the existence of biology, attempted to apply it in its then very crude condition to the production of a race of super-men, and in certain

dozen or so important biological inventions which have already been made. By a biological invention I mean the establishment of a new relationship between man and other animals or plants, or between different human beings, provided that such relationship is one which comes primarily under the domain of biology rather than physics, psychology or ethics. Of the biological inventions of the past, four were made before the dawn of history. I refer to the domestication of animals, the domestication of plants, the domestication of fungi for the production of alcohol, and to a fourth invention, which I believe was of more ultimate and far-reaching importance than any of these, since it altered the path of sexual selection, focussed the attention of man as a lover upon woman's face and breasts, and changed our idea of beauty from the steatopygous Hottentot to the modern European, from the Venus of Brassempouy to the Venus of Milo. There are certain races which have not yet made this last invention. And in our own day two more have been made, namely bactericide and the artificial control of conception. The first point that we may notice about these inventions is that they have all had a profound emotional and ethical effect. Of the four earlier there is not one which has not formed the basis of a religion. I do not know what strange god will have the hardihood to adopt

due largely to Aristotle, Hippocrates and Harvey, a few great principles such as those formulated by Darwin, Mayer, Claude Bernard, and Mendel, and a vast mass of facts about individual organisms and their parts which are still awaiting adequate generalization. Darwin's results are beginning to be appreciated, with alarming effects on certain types of religion, those of Weismann and Mendel will be digested in the course of the present century, and are going to affect political and philosophical theories almost equally profoundly. I need hardly say that these latter results deal with the question of reproduction and heredity. We may expect, moreover, as time goes on, that a series of shocks of the type of Darwinism will be given to established opinions on all sorts of subjects. One cannot suggest in detail what these shocks will be, but since the opinions on which they will impinge are deep-seated and irrational, they will come upon us and our descendants with the same air of presumption and indecency with which the view that we are descended from monkeys came to our grandfathers. But owing to man's fortunate capacity for thinking in watertight (or rather idea-tight) compartments, they will probably not have immediate and disruptive effects upon society any more than Darwinism had. Far more profound will be the effect of the practical applications of biology. I believe

ritual of their own whose infraction nowadays has a certain air of impropriety. There is something slightly disgusting in the idea of milking a cow electrically or drinking beer out of tea-cups. And all this of course applies much more strongly to the sexual act. I fancy that the sentimental interest attaching to Prometheus has unduly distracted our attention from the far more interesting figure of Daedalus. It is with infinite relief that amidst a welter of heroes armed with gorgon's heads or protected by Stygian baptisms the student of Greek mythology comes across the first modern man. Beginning as a realistic sculptor (he was the first to produce statues whose feet were separated) it was natural that he should proceed to the construction of an image of Aphrodite whose limbs were activated by quicksilver. After this his interest inevitably turned to biological problems, and it is safe to say that posterity has never equaled his only recorded success in experimental genetics. Had the housing and feeding of the Minotaur been less expensive it is probable that Daedalus would have anticipated Mendel. But Minos held that a labyrinth and an annual provision of 50 youths and 50 virgins were excessive as an endowment for research, and in order to escape from his ruthless economies Daedalus was forced to invent the art of flying. Minos pursued him to Sicily and was slain