co-ordinate what was thought or known about living things into a science, while at the same time he showed that appreciation of truth and beauty in Nature does not impair promotion of the quality of goodness of a way of life. The ethics of human conduct taught by Confucius two centuries earlier constituted a similar code of practical morality in a civilization which takes a high place in the history of man and his works.

The highest type of social organisation is that in which both material good and ethical goodness are rightly balanced. As material progress must in its nature be more striking, more patent to observation, than progress in man's ethical and social development, there must always be a lag in time between the operations of the two forces. The idea that the scientific and inventive mind is necessarily antagonistic to the merciful heart is as degrading to knowledge as it is untrue of the virtue of goodness. The gap between application of the two qualities is due to the selfish sides of human nature, and not to the increased power and supplies which knowledge provides for the primary needs of life.

It is permissible to indicate how this knowledge could be used in the construction of a new world, whether for better or worse, but no one believes that improvements of material conditions can be made a measure of ethical goodness. This, however, is what is asserted to be the position occupied by science in visions of the development of the human race in the past, present or future. It is the basis of a charge that advances in natural knowledge are inimical to the growth of the noblest attributes of the spirit of man. We have had, therefore, literary pictures of machinery being developed to such a dangerous stage that it had to be abolished, and on the biological side to conceptions of a world of planned types of inhabitants, each, like social communities of insects, with intellectually deadening functions to perform.

Literary works of this kind are parodies or satires of potentialities of applications of knowledge, and in no way represent a scientific view of the factors which have enabled man to survive and reach his present position. It is true that, by the release of atomic energy, modern civilization has been provided with the means of destroying itself, but the same power is available for making the earth a celestial dwelling place, just according to the service to which it is put. There is now, as always, freedom of choice between good and evil fruits of knowledge; and the ways in which these are cultivated or controlled will be the reply to the menace now facing civilized peoples. All who have goodness in their hearts and goodwill towards their fellows should unite in meeting this challenge to movement onward and upward.

Progressive Humanism

Faith in this spirit, in whatever way it is promoted or manifested in the works of man, is often regarded as presumptuous pride in his creative and constructive capacities and therefore irreligious in the sacred meaning of the word. The spirit is, however, associated with all aspects of intellectual and material progress which have influenced the course of civilization. Devotion to it is the religion of secular or scientific humanism, because its principles do not include knowledge of the supernatural and relate only to the practical application to life of the favourite Christian maxim of the British monk, Pelagius, "If I ought, I can".

Humanism in this sense is the integration of all influences which promote the development of the human race, whether associated with the teaching of a particular religion or not. Principles or practices which raise man out of his animal ancestry and add to his status among living creatures can rightly be termed humanistic. Their spirit is displayed in works of science as well as in art and literature; and the measure of their value is that of the opportunities these afford for improving human welfare on the highest standards that the mind can conceive and the heart will sanction.

Whatever convictions are held about the meaning and purpose of man's existence, he finds himself on a globe from which he has to obtain the needs of life, and also with a mind which can appreciate such abstract qualities as beauty and love, goodness, justice and mercy, whether seen on the earth or projected on the heavens. Modern humanism takes account of all these factors of cultural development, secular or sacred. It understands very clearly that the earth is but a temporary home, not only for the short span of individual life, but also for the whole human race. As tenants or trustees our duty is to make the best use of the resources of our heritage by the exercise of all our talents, and with the belief and hope that by so doing we are contributing to make men god-like if not godly in the sense of religious faith. So may the earth be made a part of the heavens of the universe in spirit, as it is in truth.

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DEFENCE AGAINST THE ATOMIC BOMB

THE news of any further increases in the effectiveness of the atomic bomb would at the present time be received with universal disgust or indifference. The discovery of a successful defence against it would occasion ~~partial~~ universal satisfaction and relief. It ~~may~~ be doubted whether the distribution of the world's expenditure on research between the two aspects of the subject—offensive and defensive—takes account of this world-wide prejudice in favour of survival. The publication of the recent report of the British Mission to Japan*, with its unequivocal emphasis on the defensive point of view, is therefore doubly welcome, first as indicating that the British Government does not necessarily subscribe to the view that no defence is possible, and secondly as providing a starting-point for any defensive investigation.

The plain fact, plainly stated in the report, is that an atomic bomb of power equal to those dropped in Japan, if used without warning on a large city of European construction having an average population density equal to that of London, would kill about 50,000 people, and would start fires numerous enough to be uncontrollable over an area of several square miles. The consequences of such an 'incident' can be traced in some detail, but detailed knowledge is not required to grasp the magnitude of the catastrophe.

It must apparently be assumed that a defence by counter-attack on the weapon itself—for example, by a device causing detonation before the target is

* The Effects of the Atomic Bombs at Hiroshima and Nagasaki. Report of the British Mission to Japan. (Published for the Home Office and the Air Ministry.) Pp. vi+22+24 plates. (London: H.M. Stationery Office, 1946.) 1s. net.

approached—is not feasible, and on this ground various statements have appeared that no defence is possible. No device of this kind exists for exploding ordinary bombs, but even the most convinced advocate of strategic bombing would not assert on that account that some defensive measures are not both possible and necessary.

Defence against every weapon must be based on its limitations. The extraordinary power of the atomic bomb may suggest that its potentialities are unlimited; but such is not the case. At present, its limitations appear to be three-fold: (i) it has a minimum size, and this size is, compared with other bombs, enormous; no small atomic bomb is possible; (ii) it is extremely expensive; only a nation of great industrial power can hope to produce atomic bombs in substantial numbers, even in the absence of international control of the necessary materials; (iii) if the bomb is detonated at the height required to effect maximum structural damage (as was done at Hiroshima and Nagasaki) quite elementary shelters like the 'Anderson' can be made to provide adequate protection against blast. While no direct evidence exists, it is possible that underground shelters generally would only be demolished within a comparatively limited area, even if the bomb were detonated at ground-level or below. These limitations are not removed if the bomb is made still more powerful, unless at the same time it becomes either easier to manufacture or capable of being detonated in smaller quantities.

Against some societies, then, the atomic bomb is almost useless. Consider, for example, an army, widely dispersed in trenches and dugouts, and provided with an adequate warning system. An attack by atomic bombs would, no doubt, cause some casualties by 'flashburn', although even ordinary clothing appears to offer substantial protection against it, and some would die of 'radiation sickness'. The latter, however, would not become ill for a week or so after the event, by which time the battle might be over. (This comparatively long time-lag suggests to the layman that further research may lead to a decrease in the proportion of deaths among those exposed to gamma radiation.) There would be few blast casualties if the troops were not housed in buildings liable to collapse and bury them. Possibly there might be some psychological reaction, but the experience of the last six years suggests that the survivors of a terrifying, but ineffective and short-lived, attack experience not depression but rather the reverse. The commander of an attacking force would scarcely expend his precious bombs on so unrewarding a target, and the slogan which circulated in Britain during the blitz period, "Safety first—join the Army", would, in an atomic war, become almost the literal truth. Similarly rural areas, villages, and small towns are uneconomic targets, and can be regarded as practically safe.

It is on these lines that a defensive strategy must go forward. The total 'war potential' which goes into the manufacture of an atomic bomb, conveniently measured in terms of electric power, has not been made public, but is certainly large. (The Smyth Report states that to make 1 kgm. of plutonium in one day takes a power supply of the order of one million kilowatts—half the ultimate capacity of the Grand Coulee power plant—and that a bomb requires several kilogrammes of plutonium.) An accurate estimate of the total expenditure involved, taking into account both the supply of raw material and

the industrial effort in manufacture, must now be available to the authorities. They can also estimate the proportion of 'potential' bombs which never reach the target, as a result of interference, either with the processes of manufacture or during the final stage of delivery. They are thus in a position to specify the 'minimum economic target', let us say the least important town against which atomic attack is just worth while. To do so they are forced to set a value on human life in terms of the industrial effort of the enemy; but this disagreeable necessity arises often in war, and they have not a few precedents to guide them.

It is always argued, by the protagonists of any offensive weapon, that to balance the effort expended by the attacker against the damage inflicted on the defender is incorrect. There is, according to them, a large but imponderable 'morale' effect which should be taken into account. No doubt the element of surprise does give a psychological value to a new weapon the first few times it is used, but there is not the smallest evidence that any such effect persists for a longer period. The Ruhr continued to function until it was materially destroyed. The economic effects of bombing in Great Britain were no greater, indeed in many cases they were less, than would have been expected on a basis of purely material calculations.

Given a definition of the 'minimum economic target', the government of a country threatened by atomic warfare could proceed to plan accordingly. A few industries in which concentration is essential, and of importance so great that they form valuable targets in themselves, might go underground, where they would be difficult both to find and to attack. Evacuation of large cities would be carried to an extent never before considered. The city-dweller would have to be accommodated, not in the houses of the countryman, but in temporary or camp towns of the kind which sprang up with miraculous rapidity at the time when the forces for the invasion of Europe were massing in Great Britain, and which would be not simply dormitories, but centres of a still more diffuse and decentralized industry. Obviously the problems presented vary widely with the structure of the nation attacked. They are most difficult for the highly industrial and densely populated countries of Europe; but simple to the point of being non-existent for scattered rural and agricultural communities.

The aim of the defender must be to allow, or even to encourage, his enemy to expend all his efforts in accumulating an ever-increasing stock of atomic bombs, without ever offering a suitable opportunity for using one. Whether this ideal could be achieved depends on the size of the 'minimum economic target' and, writing without official information, only the wildest guesses as to this quantity can be made. To the writer it seems that a town of 20,000 inhabitants provided with small shelters of the Anderson type or better, and equipped with an adequate warning system, would be a poor target for an atomic bomb. (The rate of progress in radar suggests that a few minutes warning of the approach of even the fastest rocket projectile may not be too much to ask.) Further, the increased use in the future of the framed multi-story construction, to be advocated both on architectural grounds and for blast resistance, might do much to solve the problem of rehousing, which even in a town of population 20,000 would be very serious.

The view is often expressed that atomic war would be the end of civilization. No doubt it would be the end of the colossal sprawling cities which at present deface the horizon of the industrial nations. The inherent badness of such cities is being increasingly recognized, and their doom is sealed even if the threat of war becomes so remote as to be inconceivable. But there is no reason to suppose that our civilization depends for its life on the existence of the big city. Room could be found for the present population of Great Britain within the present area, in towns none of which exceeded the 20,000 limit, and none of which was closer than five miles from its neighbours. Two hundred years ago there was not a town in Great Britain, with the exception of London and perhaps one or two others, large enough to be considered as an atomic bomb target. But it is at least arguable that in some respects the civilization of that period was not inferior to our own.

D. G. CHRISTOPHERSON

LIFE AND THE SECOND LAW OF THERMODYNAMICS

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WHETHER life processes obey the second law of thermodynamics or if life finds a way of evading the otherwise universal dissipation of energy has been something of a puzzle for a century. Kelvin left the matter open in his formulation of the Second Law, by expressly excluding the operations of 'animate agencies'. Since then, opinions on both sides have been expressed, although a majority would probably be found in favour of the view that any local increase of 'free' energy is compensated by a greater amount of dissipation elsewhere, or as Schrödinger has recently put it¹ in picturesque if somewhat inaccurate language, the organism feeds on 'negative entropy'. On the other hand, G. N. Lewis² referred to living organisms as "cheats in the game of entropy", which "alone seem able to breast the great stream of apparently irreversible processes. These processes tear down, living things build up. While the rest of the world seems to move towards a dead level of uniformity, the living organism is evolving new substances and more and more intricate forms."

The matter has been dangerously simplified by many writers by an over-emphasis of the entropy factor³. Clausius's statement that the entropy of the universe tends to a maximum, combined with the rather loose identification of entropy with disorder, has led to the formulation of the second law as a universal tendency towards disorder. The fact is that a decrease in disorder can be compensated by a decrease in energy, as when a liquid freezes. The most convenient formulation of such tendencies in limited systems is that the Gibbs free energy decreases in all spontaneous changes at constant temperature. This quantity is expressed by

$$F = H - TS,$$

where H is the energy or, more strictly, the heat content and S the entropy.

My attention was somewhat forcibly drawn to these matters by observing the growth of fungi such as *Penicillium notatum* in flasks. There is no question here of the absorption of energy from light as in plants. A few spores of the fungus placed in a closed vessel in the dark in a suitable nutrient medium, such as the Capek-Dox solution, containing merely sugar, nitrate, phosphate and small quantities of a few metallic salts, become in the course of a week or two a highly complex mass of living tissue. For example, Steinberg showed⁴ that the dry weight of the tissue formed with *Aspergillus niger* was frequently equivalent to 52 per cent of the total amount of sugar supplied.

Apparently a considerable increase in the complexity of the contents of the flask has taken place. The question I wish to ask is whether the 'spontaneous' change which has taken place under the influence of the spores is in accordance with the Second Law or not. To put it concretely, if the flask is kept at constant temperature and nothing enters or escapes, is the free energy at the end greater or less than the free energy at the beginning? An exact answer to this question obviously involves a complete knowledge of the final contents of the flask. If a detailed analysis were available we might conceivably draw up a free-energy balance sheet. Since that is clearly impossible, we can only make simpler and incomplete tests. The essential substances which have to be elaborated in growth processes are proteins, so the most appropriate question to ask is, What is the free-energy change in the elaboration of a protein?

Soluble proteins have been isolated having a great variety of molecular weights, from 18,000 for ribonuclease to 8,000,000 in haemocyanins. The crystallization of native proteins, their X-ray patterns, their high specificity and the ease with which they are denatured (that is, disorganised) show them to be structures with a high degree of order. The nature of this organisation is not definitely known; for example, whether the amino-acid residues are arranged in linear arrays or in flat or closed surfaces. However, the exact nature of the organisation is immaterial for the present purpose; we need only suppose that the protein molecule is a definite and unique arrangement of the constituent amino-acids.

Experimentally, the determination of the free energy of a protein would involve establishing an equilibrium between it and its constituents. No such equilibrium has ever been observed, and all the facts indicate that the concentration of protein in equilibrium with amino-acids is vanishingly small. Furthermore, although one or two cases of reversible denaturation of enzymes have been reported⁵, these almost certainly involve only limited changes in the molecule and not complete disorganisation. It would appear that equilibrium in the process

Native protein $\rightleftharpoons$ completely denatured
(disorganised) protein

is overwhelmingly on the side of the latter.

One important factor in the entropy of the protein molecule will be that involved in assembling the residues into one particular pattern, out of the many millions of possible arrangements. This quantity, which we may call the configurational entropy, is easily calculated. Suppose that the protein molecule contains altogether N amino-acid residues, made up of N_1 of type 1, N_2 of type 2, etc. The number of different ways in which these can be arranged in a linear array is