HERMES

OR

THE FUTURE OF CHEMISTRY

TO-DAY AND TO-MORROW

For the Contents of the Series see the end of the book

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THE FUTURE OF CHEMISTRY

BY

T. W. JONES, B.Sc., F.C.S.

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HERMES

Jâbir ibn Hayyan, that legendary father of Chemistry, whose name has come down the centuries in the Western style of Geber, showed his master, Ja'far al-Sadiq, his book, *Kitab al Wasiyya*—the book of his thoughts, his dreams and discoveries.

Whereupon—these are now the words of Jâbir himself—"My master Ja'far, on whom be peace! was angry when I showed him this book and said: 'O Jâbir, you have revealed the Mighty Secret of God.' (I replied): 'It was in my mind to be liberal and I wished to be bountiful and generous, for in thy service generosity and truth and frank explanation have remained with me and I have imitated thy nature. But, if thou so orderest, I will burn the book and will deliver it to no one.' He smiled, being well pleased with my words (and said):

'Do not so, for the Most High God has aided thee in this matter and has made it easy for thee. So oppose not the will of God in the revelation of this book, for no one in our time, or after us, will attain thereto except the Most High God help him and rightly direct him.' "[1]

Herein may be found the statement of faith of the Aristotle of Chemistry: the faith that made him legend and us the inheritors of Chemic Science.

The curious are referred to the authorities Berthelot, Al-Jildaki, Kopp, Ruska, Holmyard, Brockelmann and many another, for information and may find for themselves the truth of the Jâbirian legend and his service of Ja'far, who was the sixth Imam of Medina, in the eighth century, and of his sonship to that politically scheming druggist whose head fell when dread authority discovered him.

It is with the future developments of the Hermetic Art pursued along the lines of exact experiment introduced by Geber

[1] E. J. Holmyard's translation.

and mythologically patronized by Hermes Trismegistus that we are here concerned.

For many generations, unseen and unrequited, the chemist has played his part in the lives of all of us. Recent decades are notable in that his work is now respected, while his economic position is secure. In these later days natural wealth has been relentlessly exploited and waste reduced to its minimum.

The advent of chemical research has wrought violent changes in the nature of some of the world's markets: staple products have been replaced by products first discovered in the laboratory; with these new vistas have come new methods and life itself has changed. Natural and nitrogenous fertilizers, for example, have met, in synthetic indigo and ammonium nitrate, a competition that threatens abandonment of the natural products, and promises a greater command of colour and a fuller fertilization of the soil. Natural products are being quickly superseded by synthetic substitutes at lower cost, in unlimited supply and more useful form.

Chemical science, because it can be applied to the control of nature, has become a necessity to a civilization that daily acquires fresh and more complex material needs. Because, too, this science has now reached a development where it can keep step with these growing needs its importance in the daily life of the community will increase.

There are some, notably Mr. Bertrand Russell in his *Icarus*, who think that the effect of scientific exploitation has been to organize modern industrialism on the narrowest nationalist basis, harnessing patriotic feeling, inflaming greed and the competitive spirit : that the development of science threatens complete overthrow of civilization. They discount altogether the possibility of any economic internationalism except by the coercive domination of a single group.

It is unlikely, however, that the balance of civilization as we know it can be violently upset. It may quite possibly be destroyed in certain areas, but stability will tend to be restored through the influence of areas not so disrupted. There is also the improbability of any advance in methods of scientific warfare (especially through chemistry) that will lead to more than localized destruction.

Nor do Mr. Russell and others appreciate sufficiently the recent tendency of industrial organization towards international compromise. It is becoming more and more obvious that nationalist monopoly cannot hold any field for long. Increasingly capitalist enterprises are discovering nationalist isolation to be a threat to their economic existence. Thus the liaison between the great firms here and those on the Continent and in America in exchange of personnel, technical information and even financial support becomes closer year by year.

Undoubtedly there will be more wars, interferences and hindrances to this process of economic internationalization, but that it will continue, although slowly, is sure ; and this emerging consciousness of economic unity will supply the stimulus to that moral evolution which Mr. Russell so desiderates.

Science is not, however, to be regarded merely as an economic tool. It is much more. It is the systematized observation and analysis of differing kinds of matter and in its widest synthesis a philosophy of matter.

Necessarily its conclusions must always be empirical. The philosophical position of science as a whole has been revolutionized by the relativity concept. While the biologist and geologist have always realized the dependence of their sciences upon chemistry, the chemist and the physicist, much more the mathematician, recognized no such interdependence ; each regarded his particular branch as self-contained and unaffected by external scientific development. Now our outlook has broadened. Science is no longer envisaged as a series of water-tight compartments labelled chemistry, physics, mathematics, and so on, but as a diversely functioning unity in which any one function is only to be expressed in terms of all the others.

The work of Planck, Einstein, and others upon the mathematical expression of physics has affected chemistry so deeply as to necessitate an entirely new philosophic view-point and adjustment is still going on.

Before the present century all matter was regarded by chemists as rigid, and resolvable into about eighty unchangeable elements as absolute as time then appeared. Now in the light of the New Physics, it appears that matter is a kinetic equilibrium of electrical charges; it has no rigidity; the atoms divide; and the elements, of which there are ninety-two, transmute themselves spontaneously; time is relative; light has mass and the only straight path in Nature can be curved by gravity.

The chemical system underlying matter

is now viewed as one of equilibrium maintained by controlling conditions, change in which shifts the equilibrium either in the direction of increased simplicity, accompanied by partial disintegration, or else in the direction of an increased complexity, usually entailing synthesis into a new substance. The controlling conditions may usefully be described as the degrees of freedom of the equilibrium.

The dynamic atom of the New Physics is essentially such an equilibrium. The atom consists of a central nucleus of positive electrical energy, the proton, around which, in definite orbits, rotate at enormous velocities a number of negative electrical charges, the electrons. This ultra-miscroscopic planetary system *in petto* is stabilized by internal physical forces similar to those balancing the solar system. Upset of the balance appears only possible by the action of external agencies such as collision with fast-moving electrical particles, and irradiation by light of extremely short wave-length. The atom (except of radio-active elements, which undergo disintegration under normal conditions), appears to require for its disruption external forces so violent that Dalton's concept of it as ultimate and indivisible is understandable. Understandable also is the success attendant upon the efforts of Chemistry during the last century to build upon it theories of its chemical relationship that worked so well in actual practice that Professor Armstrong could say of organic chemistry: "We are able to bet in terms of several hundreds or even thousands to one, having wagered and won with such uniform success during a period of over fifty years."

The sensationalist press and the novelist of the fantastic have led the public to expect early and far reaching developments through the application of what is vaguely termed "atomic energy." But the cost of artificially disrupting so stable an electrical system as the atom does not bring it within the range of practical usefulness. Experiments show that on the average the cost is something like 100,000 times the gain, and there is no evidence that the cost could be decreased to an economic figure. It has been calculated that 1 gramme of radium would have to project its rays into a sheet of aluminium for a period of 3,000 years to disrupt the aluminium atoms sufficiently to yield 1 cubic millimetre of hydrogen. Scarcely an explosive reaction !

Under normal terrestrial conditions the atom may be regarded (for general chemical purposes) as a stable entity but (and this was where the Daltonian theory failed), the electronic configuration, the position of the electrons around the nucleus, is always vital, always germane, to every chemical inquiry.

This electronic configuration, so far as we know, is the sole predisposing cause of chemical and physical combination of the atoms. The manner of the internal arrangements of the electrons confers a condition of unsaturation upon the atom which it seeks to satisfy by combination with other atoms to form molecules.

Although the peculiar behaviour of every atom and every molecule is traceable to its electronic equilibrium, yet that behaviour is its chemical nature, and is the cause of chemical change. Because the equilibrium of every molecule is comparatively unstable chemical change can be arbitrarily controlled by man: he can vary the degrees of freedom of every molecule at will.

By altering the degree of freedom of temperature, for example, he can induce substances unattracted to each other at ordinary temperatures, to combine. Carbon and oxygen can exist side by side in perfect tranquillity, heat them together and they combine to form carbonic acid gas. Other substances, on heating, undergo disintegration; for instance, chalk, at elevated temperatures, breaks up into lime and carbon dioxide.

There are other degrees of freedom beside temperature; one is pressure, another is surface tension and another actinic light. Of these surface tension has yielded extraordinarily important discoveries: at least, we think the phenomena observed are ascribable to surface tension. If two substances are brought together in the presence of a third, this third body brings about combination of the other two substances. This *tertium quid* is called the catalyst, and probably performs its function by condensing the atoms or molecules, of the two substances on its surface, in layers one molecule thick. In this condition they are in a state of surface tension, the electronic configuration of both of them is then highly activated and they are in unstable equilibria and may combine to form a new molecule. Whilst apparently every chemical change may be catalytically induced, the catalyst acts selectively; it is not suited to promote the combination of many different compounds; in fact, it is usually found that for every chemical reaction there is but one wholly suitable catalyst. For example, the catalyst best suited for the hardening of vegetable and fish oils, by combining them with hydrogen, is nickel. Nickel favours this particular chemical change most when in the finely divided form known as the colloidal condition of matter. It appears to be the most necessary requirement for catalysis that the catalyst should be in the colloidal state. In the colloidal catalyst chemistry reaches up to, and imitates, living matter.

In organic chemistry there is a dependence on structure which masks the electronic equilibria of the associated atoms. In fact, so dominant is this structural arrangement of the carbon atoms that their chemistry is the most homogeneous branch of the science. Predictions of the behaviour of any newly synthesized molecule can be made from a study of its structure alone, with the accuracy that Professor Armstrong's words predicate. This property of structural integration separates the carbon atom from the rest of the elements, except possibly boron and nitrogen; in all probability, although we cannot say so with certainty, it is the property from which arises its employment in the structure, without exception, of all living matter.

The molecule of living matter, like any other, exists in a state of equilibrium changed only by alterations in external conditions, the degrees of freedom; by reason of its internal structural arrangement, it possesses to a marked degree a certain adaptability to external conditions. This indicates an internal adaptability, although of only an elementary degree, to environment—a property peculiar to the living organism.

The rôle of the catalytic degree of freedom becomes more important and more selective the further we advance up the range of organic molecular complexity until, in living integrations of matter, it reaches its apogee. It is natural that this should be so, for the living organism depends for life on the change of its food into molecules which it can temporarily synthesize into tissue and then break down again. Temperature and pressure are degrees of freedom that cannot be used by the organism, since it has only a limited tolerance for them. The organism has, therefore, to rely on substances which work independently of high temperatures and pressures to convert its food into simple molecules and then to synthesize them again into tissue. These substances, which most probably act catalytically are exceedingly complex, and appear to possess a peculiar adaptability which enables them both to break up, or hydrolyze, the food molecules into something simpler, and then synthesize the resultant molecules again into complexities required by the organism. Hence, in living matter, the catalysts by which life is maintained are kept in a condition of equilibrium so that the sum of their synthetic and hydrolytic catalyses may be balanced in the direction required for the furtherance of the living whole of which they form a part. Since disintegration is death, the balance of the vital catalyses must be weighted on the side of synthesis, or, as Jacques Loeb put it : " The matter between life and death is not between living and dead molecules, but more likely between excess of synthetic over hydrolytic processes." " La vie, c'est la création," said Claude Bernard.

So far as we have investigated them, the vitamins appear to be the requisite external degrees of freedom to control this equilibrium in human life ; they balance it in favour of the synthetic process, for in their absence the so-called deficiency diseases supervene, and lead, finally, to death. They appear to act catalytically to balance the syntheses of life over the hydrolyses of death. One may perhaps regard them without incongruity as the super-catalysts of vitality controlling the body's own catalysts. Unfortunately, we know as yet very little about them, but, as far as we are in a position to judge, the human body seems unable to make the vitamins it requires or to store them for very long ; it requires constant supplies of them ; yet the lower forms of life, the micro-organisms and plants appear to make them and to store them with ease. Man and the higher animals, it seems, depend entirely upon these lower forms for their supplies. Whatever they may be, and however they may work, the vitamins appear to act as most potent degrees of freedom for the animal equilibrium.

The chemist then finds that all matter consists of individuals, or wholes, as General Smuts in his *Holism and Evolution* has called them, which are each and singly maintained in a stable condition of equilibrium by degrees of freedom, external and peculiar to the stabilized system. As matter is integrated, so are its degrees of freedom ; for every whole and individual integration there exists its peculiar degrees of freedom which alone maintain its inner harmony. Yet, in all matter, and especially so in living matter, there appears to be an internal selectivity that utilizes, within the limits of its equilibrial range, the degrees of freedom for its own purposes.

This concept of the self-regulation of the whole is, of course, implicit in all Loeb's work, but both he and Smuts appear to miss the significance of the degree of freedom. This self-regulation, as integration proceeds, appears to become more and more selective until, when we come to life, it may possibly be synonymous with life. If we do not find it so, then there appears no alternative to a mechanistic philosophy wherein the degree of freedom becomes identified with the external directive force, so at variance with all Loeb's ideas, that was put forward by Claude Bernard.

It is extraordinarily significant of the homogeneity of matter that its chemical nature, in whatever degree of integration examined, is found to be based on one single system the balance of which is revealed as dependent ultimately when traced to the foundations, upon the electronic system of the atom. It is evident that all science must be as homogeneous—as consistent—as the matter it studies: the sciences of the Victorians are all one, and chemistry but a phase of scientific discovery and progress. But at the same time sight should not be lost of the fact discovered by chemistry that for all practical purposes of living matter the electronic condition of the atom is only displayed chemically; hence the study of the higher forms of matter rests on a chemical foundation, to which they may be reduced, and upon which they are built. The application of chemical science to matter is, therefore, the only efficient method of controlling it for the needs of mankind. As yet man is scarcely aware of this fact, but he is learning fast and moving with sure steps to the chemical exploitation of material resources; a necessity to the overgrowing complexity of life.

As a dynamic entity man needs energy, and he obtains it from his physiological use of food. In the civilized state of an organized society, however, wherein the conditions of urban and similarly densely populated areas necessitate the wholesale transportation of food, he must have an additional form of energy, namely, fuel for locomotive purposes. To Isolated Man, as the economists have christened him, food is the essential and mechanicalized transport a superfluity. What direct service unobtainable from his own hands and feet could Robinson Crusoe have got from an aeroplane ? Only that of escape, which, once achieved, would have immediately disqualified him as a self-contained economic unit.

To commercialized man, on the other hand, transport must be ranked as one of the primary needs, if not the first essential, of his civilized state. Without it he must face reversion to a condition of barbarism approaching more or less nearly to that of the economists' Isolation. The highest state of social integration possible under the conditions arising from an entire elimination of every form of transportation more mechanical than the horse and cart would be akin to that of the eighteenth century when famine was not unknown and was, indeed, a possibility to be reckoned with by most of the population. The last state would probably be worse and dearth become the seasonal event it is in all primitive societies. It would very likely be possible to show that lack of mechanical transport, as well as disease, lay at the root of the troubles of all earlier civilizations and without it they were doomed to disintegration. Since we may expect still greater improvements in transport we may assume progressively higher integration, as transport is the key-stone of social life and culture—food is but that of population.

The transport of the future, one may suppose, will be mobilized by electrically and thermally driven engines, whether it be road or air traffic.

Since our supplies of coal and petrol are limited to the amounts stored in the earth, the day will come when they are exhausted; but new fuels will have been synthesized to take their place as sources of power for thermally-driven traction, for it is probable that for certain types of transport we shall always rely upon thermal power ; fuel is easy to carry and store, and confers on the vehicle using it independence of movement, complete mobility ; whereas the mobility of electrically-driven vehicles is restricted either by the conductors through which they receive their power, or by the capacity of their storage batteries ; the superior mobility of the thermally driven vehicle makes it a factor of cardinal importance, although our harnessing of the water power of the world to hydro-electric turbines could probably supply all our demands for energy for every purpose, including that of transport. Indeed some of the hydraulic power of the future may be diverted to the electrochemical synthesis of fuel ; we may find some mineral other than coal to supply the requisite carbon to burn in our combustion engines.

To return to " atomic energy," briefly

touched upon earlier. It has long been prophesied that in the future we shall supply all our needs of energy directly from that of the atom ; the energy of the atom is said to be such that a cupful of water could drive the finest of the Cunard fleet from Europe to America and back. It would probably take the hydro-electric power of Lake Erie, spread over a number of years, to disintegrate completely the cupful of water. Furthermore, the prophecy argues from false premises ; it takes for granted that the nature of atomic energy is known and differs from other forms of energy ; whereas we can, at present, only guess at its exact nature. We know that its equilibrium is electrical. We already use electrical energy, and, if we are to gain nothing more than we have at present, it is difficult to see wherein lies the advantage of this over-rated "atomic energy." The most we can say at present is that it *may* turn out to be a fresh material force, and *may* be harnessed ; but there is not, at present, the slightest indication that it will, nor that our traffic problems of the future will be resolvable by any energy other than that derived from our resources of water and fuel.

Now it is only a matter of time before our petrol reserves are all used, and we have to find some other suitable fuel in equally enormous quantities; for it is not to be expected that the benefits of the light internal combustion engine, thermally a highly-efficient apparatus, will be surrendered either by business transport, or by *paterfamilias*, who, over the week-end, derives from it much of what the economists assure us is an indirect satisfaction of economic need. There is little doubt that we shall find this fuel, and find it in the chemical factory; probably long before our supplies of petrol are exhausted. Once it can be produced in commercial quantities it will be in strenuous competition with petrol. The decisive factor in the disappearance of petrol from the world's markets may then well be the strength of counter competition it can achieve, rather than the exhaustion of its deposits. Mother Earth could then keep her stores of mineral oil; it would not pay man to take them. It was at one time predicted, and no longer ago than 1905, that the deposits of Chilean nitrates would be exhausted and the world left without fertilizers for its crops: to-day Chilean nitrate meets only a third of the world's needs, and except for a fraction made in gas works, the remainder is made synthetically. Perhaps petrol will follow this example and oil-profits dwindle as the nitrate profits have done; it all depends on the length of life of the petroleum deposits, and the cost of its production. Synthetic substitutes are imminent.

The eccentricity which Nature, like a French peasant, displays in hiding her wealth, renders all man's computation futile. Estimates of both must be limited within predictable bounds, but although the peasant's maximum possibilities may be judged with fair accuracy, by a careful observer of the habits of his class and race, nobody has the requisite knowledge to define the extent to which Nature may have saved. Estimates vary as widely as eight to eight hundred years. The best informed place the oil left in the wells of the United States, the biggest single producer of oil, at barely six years' supply, with a problematic twenty years' supply from shale deposits. True, the United States is a single producer, but in 1924 those wells yielded 70.5% of the world's petroleum. In the same year American motorists consumed 73.8% of the world's petroleum. The most prolific producer found his supplies insufficient!

The near future will witness the manufacture of a number of fuels. Some will be heavier grades of oil, yet still competing with petroleum fractions for the patronage of owners of Diesel and similar heavy engines.

At the present time there is extraordinary activity in laboratories all over the world to this end: much of it will be abortive—man has to experiment to learn

—but the net result will provide an extremely wide range of fuels suitable for all kinds of engines. It would be premature to enumerate them: they all rely upon obtaining from coal of some kind, the cheaper the better, an hydrogenous liquid product possessing properties as closely resembling petrol as possible. The methods of getting them vary; some compress the coal with hydrogen and a catalyst, as in the process known as the Bergius process, which yields a liquid very similar indeed to petroleum: some use coke which they burn partially to carbon monoxide, combining this with hydrogen catalytically at high temperatures and pressures to obtain a simple alcohol, methyl alcohol. This particular process is now being carried out on a big scale in factories both in Europe and America; however, it is not the best of fuels for the ordinary motor car engine; but the process is interesting in that, by it, under slightly different conditions of temperature and pressure, it is possible to obtain certain compounds chemically identical with those in ordinary petrol. Another method, that is being worked on a large scale in Germany, heats together coke and lime, from which by way of acetylene, ethyl alcohol, ethanol, is synthesized catalytically. So far none of these is competing with petroleum, but when they are developed a little further and processes cheapened sufficiently, they will come into the market for that purpose, besides, of course, those they now supply. Their advent is only a matter of time ; probably by 1935 other synthetic fuels will have been evolved by the chemist, and the motorists of that date will find a difficulty in making a choice from the numerous pumps then lining the kerbside.

As all these synthetic fuels are derived from coal the duration of their utility must depend upon the life of our coal supplies. Here there is no cause for apprehension of a shortage in the near future. The world's supplies of coal are comparatively enormous, being estimated at about a hundred billion tons; and it is as well they are, for they are annually drained at the rate of over twelve hundred million tons; a tonnage approached by no other commodity. Since the average yield from a ton of coal is fifteen hundredweight of coke, practically all of which may be used for synthetic purposes, it is obvious that a final extinction of the motor-car through lack of fuel need not be feared. Because a growing use of transport of all kinds coupled with a probable exhaustion of petroleum, or at all events a diminished production of petroleum in the near future will make increasing inroads upon the coal reserves, the present estimated life of 3,000 years for the coal-mining industry may have to be reduced. But it appears that, in all probability, besides those economies resulting from the hydro-electric developments of the future, others will arise through changes in the use of coal.

At the present time most of the coal is burned in the same condition as it is mined; volatile constitutes, so valuable for the manufacture of synthetic dyes, drugs, and perfumes, are wastefully sent up the chimney as smoke ; befouling our cities with an atmosphere that effectively clogs them against penetration by sunshine, and prevents the entry of fresh air. A change in our use of coal would have in its support the forces of cleanliness, health and economy. These, however, do not appear sufficient to persuade us of our errors, and the Royal Commission of the Coal Mining Industry, in 1925, actually hinted that it might be advisable to add the force of legal penalization in order to ensure adequate pre-treatment of all coal.

Of the various methods suggested for pre-treatment, that of distillation at low temperatures is the most generally supported at the present time. This is claimed to be the most efficient, as it extracts from coal the majority of the volatile constituents, including gas and motor fuel (the yield of benzol—the motor fuel directly distilled from coal—is three times greater than that obtained by the usual gas works practice), a tar containing all the essentials for the dye-stuffs and disinfectant-making industries, and a smokeless coke that can be burned in domestic grates as easily as raw coal. Incidentally recent experiment has shown that the open fire of the English domestic grate is healthier for the occupants of the room than any other type of heating—we may yet live to see America and the Continent copying our so-called antediluvian ways of heating.

This method of low-temperature distillation almost certainly will become general practice when various technical difficulties have been overcome; for, despite the claims of its enthusiastic supporters, who point to numerous experiments, in Glasgow and elsewhere, there are still drawbacks that, at the moment, make it commercially unprofitable. It is, however, the nearest approach we have yet made to the ideal use of our most valuable natural heritage; the nearest approach to the mode of exploitation of mineral wealth an economically determined community might be expected to adopt. At present the only economically-minded members of the community appear to be the owners of gas-works, and they, it is claimed, waste more than they would if they worked their coal at a lower temperature. It is not, however, on the increased yield of motor spirit that the supporters of this method base their advocacy—indeed, it is difficult to see how they could, since, were *all* the coal annually mined by the world so treated less than a tenth of our present requirements for motor fuel could be met—rather do they rely upon its promise of the abatement of smoke ; in consequence of the artificial removal of all the volatile constituents of the original coal, the coke burns freely and without smoking ; consequently, there is no smoke to befoul the atmosphere, to dirty buildings and encourage the spread of phthisis among their inhabitants. The supporters believe it will ensure cleanly cities and healthy citizens. Whether governmental coercion, as hinted in the Royal Commission's *Report,* will be required for its universal adoption is doubtful, it is more likely to result from private enterprise by reason of the control that could thereby be exercised over the raw material of both the chemical and synthetic fuel industries of the future.

The pronounced tendency on the part of modern manufacturers towards vertical combination, to ensure adequate supplies of raw materials, leads one to expect that the coal supplies of the future will be controlled by chemical manufacturing syndicates. If this should come about, it may well happen that a large proportion of the world's coal will be subjected to preliminary carbonization for the sake of its chemically valuable distillates; such of the coke produced as may be required for synthetic fuels will be retained, and the remainder passed on to the domestic and industrial consumer. The householder of the future may find that the only fuel available to heat the home will be smokeless, and he will be prevented, willy-nilly, from polluting the atmosphere. Unlike his modern prototype, who is responsible for most of the dirt of the urban atmosphere, he will enjoy in a town dwelling all the freshness and sunlight of a country climate—gas-works will be relegated to the mining districts, whence all gas will be distributed over the country by pipe-lines.

Further economies in the consumption of coal are bound to come by the development of hydro-electric schemes. The electrical power will, by the ingenuity of the electrical engineer, be distributed to all parts of the earth's surface, gradually supplanting thermal power for all purposes except those of independently mobile vehicles: the numbers of these will finally be reduced to the minimum. Railways will probably be the first form of communication to be completely electrified. A close second will be the bus-routes; the electric tram may at last vindicate the faith of Manchester, and the motor bus may then be superseded both for urban and country services by some form of the trackless trolley.

To-day the chemist's most valued assistant is the electrical engineer; with his help he first made synthetic fertilizers from the air, and separated aluminium and beryllium from their ores.

Judging from the proceedings of world power conferences the activities of the electrical engineers are nowadays devoted to hastening the final conditions of terrestrial configuration wherein every valley shall hold its lake, the annual rainfall for which is assured by forests—spreading from the water's edge to the snowline—in which the holiday-makers of the future wander during summer days; and in the winter the proprietor or, probably more accurately, the holding syndicate, cuts the areas scheduled annually for the making of paper and other commodities future discovery may make possible from timber, bark and roots (metal will have superseded timber for building purposes). At the lower end of the lake small boys slide down the pipes to the turbine house. In that millennium all houses will be electrically heated and lit, cooking will be electrical, as we shall at last have exhausted our coal and be dependent upon the carbonates of the earth for carbon. Chalk will provide the fuels of our aeroplanes and motor cars. Chemical science will have evolved an electrical conductor that will efficiently transmit current from Swiss turbines to the cliffs of Dover, to separate pure carbon from the chalk. Electrically driven pumps will deliver the waters of the Straits to electrolytic cells on the cliff-top from which the hydrogen will pass to a catalytic chamber and there, with the carbon, be synthesized to a fuel better than any we have ever known. Visiting Gauls will look in vain for the historic landfall of Albion.

It is difficult to foresee any innovation in the principles of vehicular construction whether designed for aerial or terrestrial service. We seem to have exhausted the possibilities. Vehicles will probably continue to be boxes of one kind or another, open or closed, provided with skids, wheels, keels or wings. New methods of moving them are improbable; we have driven them by external agencies—animals, wind and gravity, and by internal engines—steam, electricity, gas, and man-power.

We may, and probably shall, see changes in constructional materials. Even here the novelty will be confined to degree rather than kind. The constructional material of the future will be a metal, or rather alloy of metals, mainly for the reason that our timber will have been exhausted; stone and cement being dismissed as obviously unsuitable. The supply of metals may be taken as inexhaustible; the whole of the earth's surface, so far as we have penetrated, consists of chemical compounds of the metals, the only obstacle to their use is the difficulty of separating them. This will be surmounted in time.

The need of aeroplane construction is

obviously one of lightness combined with strength. For this we must rely upon the lighter metals. But they have the disadvantage of mechanical weakness, unless suitably alloyed. Promise appears to lie in the direction of alloying aluminium and beryllium, very nearly the two lightest metals, and research upon these is being pursued diligently both in Europe and America. A German firm, the Chemische Fabrik Greisheim Elektron, claims to have produced a suitable alloy somewhat less than twice as heavy as water. Safety, particularly for trans-oceanic passengers, will be assured when an alloy capable of floating upon water has been invented; lithium would do as an alloying metal, but it would either have to be crystallized in some special way or alloyed with a heavier metal to increase its strength and chemical resistivity. Travellers of the future may demand a chemical analysis of their aeroplanes before trusting themselves in the air between London and New York.

It is long since the roof-tree was the only alternative to the cave. In considering building materials of the future we have to take into account a certain exhaustion of our timber supplies ; an exhaustion, moreover, that according to the experts, will not be long delayed. It is computed that already European demands exceed the annual growth of soft woods by about three thousand million cubic feet. Soft woods, it is true, are not bought entirely by the building trade, but are taken in bulk by the paper trade. But they are quick growing and hence offer greater attractions than the slow-growing hardwoods to the speculative grower, and we may take it that the annual replenishment of our supplies is confined more or less entirely to these soft woods. It would seem, therefore, reasonable to suppose that the annual proportional excess of consumption over growth for building timber is definitely on the wrong side. Supporting evidence is not lacking in the price of the better quality hardwoods like oak, mahogany, maple, and so on, which are, except for what may be termed *de-luxe* building, used exclusively for furniture making. Presently the hard woods of the furniture trade will be replaced by the better-class soft woods, such as pine, although it is doubtful whether the paper industry will not outbid all other buyers, even though wireless telephony and television modify the demands made by the daily press. In that case the furniture trade will have to rely, like the building trade, on metallic materials : fortunately chemists have already made some preparation for the eventuality : it is said that quite pleasing and permanent decorative effects can be obtained on aluminium and copper by suitable chemical and heat treatment.

Steel and iron are the very bones of the modern city ; carefully articulated steel-work is the chief support that permits us to crowd upon a few acres of soil. The multitudes that apparently must be concentrated for the maintenance of commerce and administration, whether it be office or factory, have made inevitable the superposition of one floor on another. The bungalow plan of the cave is useless to business, however suitable it may be for dwelling purposes. We shall find metals used more extensively in dwelling houses, as timber becomes scarcer; we already have metal windows, baths, and fireplaces; we already have, even if experimentally, metal doors, picture-rails and stairways; metal office furniture is to-day selling readily in London.

All-metal houses cannot be expected to become the final word in accomodation that all-metal vehicles obviously are in transport; we have tried them, and must doubt whether the idea will survive the types erected in 1920—1926 which were planned to meet the housing shortage.

The cheapness and the general utility of bricks, stone and cement, make their supersession by metal very improbable, at all events for external use. Cement offers most possibility of development; the builders of the Middle Ages showed us what could be done with stone, and the Georgians the resources of brick ; we shall possibly show the future the plasticity of cement ; it remains for the future to build with synthetic glass and other organic plastics—if the raw material can be found in sufficient quantity.

The first thing we have to do with cement is to invent an impervious lightweight variety of sufficient internal tenacity that it may be poured *in situ* to form thin, continuous roofs, quick-setting so that it may be used for the sloping roofs of northern climates. This will assist considerably in reducing building cost to a level we have almost forgotten. Cement has the advantage over other stones, in that being chemically compounded the ingredients may be varied at will, to yield a variety of results ; to-day chemists are busy exploring its plastic and harmonic potentialities. Perhaps one day the architect will arise who can really build in form and colour with cement, instead of the restricted lines into which it is compressed to-day: lines more suggestive of the rigidity of timber than the grace of a freely-flowing mass.

With regard to the clothing of the future, the clothing manufacturers will undoubtedly compete with the paper industry for its raw materials—or rather the textile fibre makers will—for these at the present time find in sulphite wood pulp their cheapest raw material (cotton, the alternative form of cellulose, to-day costs approximately 5d. per pound as against 2d. for the pulp). If a diminishing supply and increased demand by the paper makers have the effect of raising the price of pulp, obviously cultivation of cotton will be increased, and the day may come when the cotton field is very nearly the sole source of clothing, and possibly also an important source of news print.

The chemist finds in artificial fibres the most fruitful solution of man's growing shortage of clothing. At present, in point of quantity, cotton is the chief textile fibre;

the second is wool; next comes artificial silk, and among the rest is natural silk. After the fig-leaf and skins, wool was man's first covering, and so continued through the Middle Ages up to the beginning of the last century; then, thanks to the slave trade, cotton supplanted it. To-day artificial silk runs next to wool, and in time will probably overtake it, as cotton did. Cotton has succeeded by its cheapness and ease of cultivation: the yield per acre is considerably more than from wool: the crop is annual and seasonal fluctuations are more easily wiped off over a period. Cotton, however, fails by its lack of brilliance and its general lack of artistic qualities: it is a dowdy textile. Treat it chemically and it equals silk. This is the secret of the success of the artificial fibres, which are derived either from sulphite wood pulp or cotton fibre; for little more than the cost of dowdiness they make their wearer the glass of fashion; by chemical art, social barriers are transcended and factory women can closely follow "the mode." Natural silk is a waning industry, all the silkworm areas are now building viscose and cellulose acetate factories; Lyons and Italy are leading the change.

Artificial fibres are superior to cotton in other ways as well; their manufacture is independent of season and situation; employment in the industry is steady with none of the fluctuations and uncertainties of silk weaving; they cost the wearer less whilst benefiting the manufacturer more. Hence their expansion will continue until a more economic solution of the clothing problem is invented.

Mankind's clothing marks the several stages of our civilization. Anatole France and Thomas Carlyle are agreed on this, and we may accept their testimony as valid. The conventions of civilization were roused the instant France's Saint clothed the penguins: "Clothes gave us individuality, distinctions, social polity": "Clothes made Men of us," wrote Professor Teufelsdrockh. Indeed, through all

Western literature runs the thought that clothes have a civilizing influence.

Given the same population, the same quantity of clothes will be required, no matter the extent of sophistication. Since however, we are to expect an increasing population, we have to seek increasing quantities of fibre to maintain it.

The source of future supplies will undoubtedly be cotton, at any rate, so far as the bulk of clothing is concerned, since supplies of sulphite wood pulp may not more than meet the requirements of the daily press ; other annual crops will continue to supply a part, as they do at present ; as, for example, linen, hemp, and other bast fibres. But cotton is the purest natural form of the important cellulose molecule and as shown by the statistics of the past century, its rate of growth is sufficiently elastic to meet all demands upon it, and by chemical treatment its natural condition may be altered to suit any purpose for which it may be required. Artificial control, whereby the cellulose molecule can be synthesized into something more complex, places the whole question of clothing entirely, and at last, within the scope of chemistry. No longer shall we remain content to waste energy in attempts to imitate animal furs and wools, and vegetable stalks and seeds, so that what protected the beast or plant from sun and rain shall also protect us. So far manufacturers have confined their efforts to imitations; to out-silk silk and out-wool woolliness; presently they will awake to the fact that the ideal fabric has yet to be evolved—we have contented ourselves with a second-best.

The imitative stage in colour has long been passed. Coal tar dyes, thanks to Perkin and the Germans, are synthesized no more to imitate the colours of nature, whether of autumn or spring; the pattern cards of dye-stuff firms display a multitude of syntheses that transcend Nature to reach almost a philosophic satisfaction of the aesthetic sense of colour. When the problems of durability, both as to washing and sun, and—such is, unfortunately for the Higher Thought—the effect of the body on its clothing—to sweat also have been solved, the corporeal needs will have been satisfied.

Artificial fabrics are synthetic in a small degree so far as they are so by human agency. The major part of the synthesis is carried out by the plant, which can build up complex molecules from the soil and the atmosphere far more cheaply than is possible in the factory. It is only the final stages that are commercially profitable in the laboratory in the case of a molecule as complex as cellulose. Further development of the natural cellulose resources of the earth will lie in assisting the natural synthetic processes, by evolving a plant to yield the maximum of cellulose and providing it with soil containing its food in the simplest condition. Development economically will be in the breeding of plants capable of productivity in climates now unsuitable. We may find it necessary at some time to extend the cotton belt to latitudes where at present cotton is unknown, in the same way that the wheat belt has been shifted in Canada.

A product depending upon cellulose is the nitro-cellulose paint or lacquer. This may compete severely with the textile trade for the cotton which is its raw material—the final product being similarly partially synthetic. For this the highest quality of cotton is required, although doubtless, with improvements in technique less valuable qualities could be used.

Nitro-cellulose lacquers and paints in the very near future may form the sole means of protecting all exposed metal and wood-work; they will replace the oil and shellac media now used. The nitro-cellulose lacquer or paint is, to quote an authority, "unaffected by sun, rain, snow, or boiling water, salt air or alkali dust"; claims which cannot be made for other protective coverings; if they reduce the world's paint bill by only a quarter, they will have justified their invention. It is probable they will do more than this. Indications of their growing use are to be found in the fact that, whereas in 1918 they were unknown outside the chemical laboratory, in 1925 Great Britain and the United States, between them, manufactured 11,075,000 gallons. Paints and varnishes as we know them to-day obviously cannot sustain such competition. Their going will make economic changes of world-wide importance. Of their ingredients, some will find new markets; others, failing this, will cease to be produced, thus compelling workers all over the world to seek more modern occupations. The turpentine production of the world will probably not be changed since turpentine is already wanted for conversion into synthetic camphor for the celluloid and nitro-cellulose lacquer trades. The rosin may be similarly treated or will form a raw material for the synthetic resin trades. The oils will be the most difficult problem. The most used of them is linseed oil, obtained from flax seed. It is thus a by-product of the linen industry and unless it can be absorbed in some manner, the difficulty of disposing of it may result in an increase in the price of linen and, possibly, a gradual dying of the linen industry. The only use the oil could be put to would be the manufacture of foods, since the soap trade would presumably be already flooded with other oils, notably the cotton seed oil from the increased cotton crops. In addition to linseed oil, which is mentioned specifically on account of the enormous quantities produced and the effect its disappearance from the market would have on the linen trade, a use would have to be found for the other oils of the paint trade. Fortunately catalytic hydrogenation would render them valuable to the food trades. In this, however, we are already anticipating the future. At the present time, something like 300,000 tons of vegetable and fish oils are hydrogenated annually by European factories alone, and a large proportion of the resulting fats are used for food.

For many years prophecy has been busy

with the food of the future, predicting such a variety of diets as to make further prediction appear, not so much superfluous, as fantastic. But there seems little reason to suppose that the final food will differ greatly from the present except in regard to its digestibility—in which there is still great scope for improvement. Vegetables and fish will tend to predominate, but butcher's meat, on account of the high economic costs of its production, will probably disappear from the diet of a civilization forced to depend more and more upon the higher yields obtainable from the acre by annual crops.

The foods synthesized from coal and coal tar that have frequently been predicted are never likely to materialize; the cost of their production would make them a luxury in any age and particularly under conditions wherein proper cultivation will yield cheap and plentiful supplies of natural foods, or natural foods slightly elaborated by synthetic art. Partial synthesis, whereby an inedible substance can be made palatable and of dietetic value will always be a commercially profitable practice provided the costs of operation are sufficiently low to enable it to compete with the natural food as, for example, they are in the case of the catalytically hydrogenated vegetable oils used to-day for margarine and other fatty foods. But complete synthesis, from their elements, of complex molecules like the carbohydrates, proteins and fats of foods, it is safe to predict, will be too costly except for special purposes such as laboratory experiment. Simple molecules, like alcohol and ammonium sulphate, involving only a few, comparatively simple, processes, are already profitably synthesized from their elements; but simple molecules are not suitable for the human diet except in small quantities at a time, for man's body is built and run on complex molecules.

The value of food is measured by the amount of energy, estimated as heat, into which it can be converted. This perhaps is not the ideal measure, but it is the best we can do at present, and it served us very well during the war. For a man to do a day's work, repair the usual wastage of the body and put by reserves, the total heat value, according to the well-known Voigt ration, should be 3,000 calories. This is provided by 100 grams of protein, 100 grams of fat, and 400 grams of carbohydrate—carbohydrate, fat, and protein are the three chemically generic classifications of all food. Of the three, the protein, or nitrogenous class can be used for both body-building and supplying energy ; the other two, the fats and carbohydrates, the latter including the starches and sugars, only supply energy, and the fats more slowly than the carbohydrates. Protein and fat have been in the past provided in a diet restricted to meat, hence the ability of primitive and nomadic peoples to live by hunting and their flocks. In addition, the body requires supplies of salts and the newly-discovered accessory food factors, the vitamins.

The vitamins appear essential to healthy, normal life ; without them growth ceases, disease runs riot and the body soon dies. Fortunately for our early ignorance, a normal diet contains all we need of these essential *elixirs* of life. What they are, whether new and unknown molecules or molecules already known, but specially activated, we have not yet discovered ; our only information is that there are five types—there may be more—lack of any one producing the so-called deficiency diseases peculiar to the type.

Considering the complexity and definiteness of these requirements, it is exceedingly difficult to understand how a hearing was ever granted to some of the prophecies of the liberties man has been expected to take with his stomach. Take the tabloid theory, in which a tabloid a day is to satisfy man's hunger and provide him with enough energy for work and play, health and strength, grief and love. One can but imagine that the tabloid, weighing, presumably, a couple of grams at the most, would consist of a selection of extremely efficient catalysts and vitamins, capable of rendering man able to synthesize from the air the remaining 598 grams of food required by the Voigt ration, perhaps as the plants do by the aid of chlorophyll. It is a pity that man's skin cannot do this, as the clothing problem as well as the feeding problem would be solved, since man, one concludes, would go naked in order that his body would deal with the maximum amount of air; incidentally, it would throw out of employment a large proportion of the population. Lancashire and the East may breathe freely: man will continue to require the equivalent of 3,000 calories, woman 2,500, and the baby somewhat less.

Chemical science, already playing an important part in the preparation of natural foodstuffs, is bound to influence, and, to a certain degree, to control the development of both the nature and extent of future food supplies. The foods of to-day, except for the gathering of a few casual crops, like blackberries and mushrooms, cost the populations of the civilized world much more than merely the trouble of harvesting and eating. Throughout there is a highly organized preparation of food for the consumer. In this the chemist bears an increasingly active part, providing disinfectants for the seeds, manures for the ground, other disinfectants for the plant and fruit, supervising packing, treatment and distribution, to ensure that the consumer obtains his food in the best of condition, whether it be wheat, fruit or meat, fish, flesh, or fowl.

In the future, besides this work of a more or less routine nature, chemical activities may be expected to expand very considerably in view of the developments that are foreshadowed by contemporary research in the breeding of plants and animals for food : soil irrigation and, not least, the internal organization of the plant present essentially chemical problems exercising fundamental influence upon both the quality and quantity of food obtainable from them.

The maintenance of numbers as required by growing density of the population appears to be impossible upon the comparatively sparse yield of animal food obtainable per acre. It is significant of modern conditions that in highly civilized communities where in economic phraseology, the marginal returns from land are so narrow as to occupy the minimum of space on the farmer's balance-sheet, intensive growing of crops is the rule rather than the rearing of herds. The production of meat is relegated to the wilder lands of the earth where population has not yet condensed. With increase of population, these lands gradually come under crops, herding being a transitional stage between virginity and fruition. The food equilibrium of the world turns increasingly in the direction of planting. Even in herding there are epochs; the present sources of frozen meat upon which the denser populations of the earth now rely for their protein were originally developed not for the meat so much as the wool and leather. Before the advent of refrigerated transport sheep were bred for their wool and cattle for their hides: meat was a by-product to be rendered into tallow before putrefaction had gone too far. To-day the tanneries and wool-sheds are subsidiary interests beside the freezing plants: artificial fibres and rubber will make them increasingly so. Unsupported by its by-products meat will depend for continued production upon a lack of competition by alternative forms of fat and protein. It will not be lacking however; fats are already available from the by-products of cotton—the very crop that will replace wool and leather.

The production of meat, it appears, therefore, will very probably cease unless the food yield from a given area can, by breeding and feeding, be brought to a point when it passes the food value of the 35—40 bushels of wheat obtainable from the acre under careful cultivation. Furthermore, as a source of protein, it can be replaced by wheaten bread, fish and some of the vegetable oil seeds after extraction of their oil. For example, soya bean, besides providing the Western world with soap-making oils, provides the Far Eastern populations, notably of Manchuria and Japan, with various foods very similar in composition and taste to milk and cheese ; and already experiments are being made to devise a means of eliminating the toxic ingredient gossypol, from the protein of the cotton seed. The provision of both oil and protein by land crops will probably render futile the present researches being undertaken to conserve and increase our supplies of fish ; the intensive oceanic cultivation, predicted for the future, which would emulate the oyster breeding and whaling activities of the present day, is never likely to come about. The world will never see its oceanic littoral a chain of fish farms as continuous as its present chain of holiday resorts, with the consequent confinement of the annual seaside holiday to the cliff top, whilst keepers and poachers war beneath on a beach jealously guarded by the fisher-farmers.

For carbohydrates the world depends to-day on a number of crops, the chief of which are wheat, rice and sugar. Statistics of recent years point to an increasing consumption of wheat on the part of previously rice-eating peoples, since the increase is more than can be accounted for by the growth of the naturally wheat-eating population. Hence, if Eastern peoples continue in their adoption of Western culture and habits of life, one may conclude that wheat will gradually become the predominating food crop of the world. The greater vitality of Western peoples compared with Eastern can, with some justification, be attributed to the gluten content of its wheaten staple of diet. Gluten provides the protein requisite for body building, and its absence from a rice diet explains, according to experts, Oriental lack of physical stamina. Providing, as it does, both protein and carbohydrate, fat and vitamin, wheat is, literally, the staff of Western life.

We can increase our supplies of wheat either by increasing the acreage allotted to it, or by increasing the yield from that already under cultivation. Of the two the latter will probably be adopted later, when all suitable virgin land has been taken up, when it will become a necessity. The obvious method of improving wheat bearing land is by fertilizing artificially : by this means Denmark obtains an average yield of 41.8 bushels from an acre. Without it South Australia obtained in 1898 an average of 7 ; in 1898 the average yield of the United States lands was 12 (the yield established at Rothamsted Experimental Research Station for unmanured land is 12.6); with the aid of fertilizers the United States yield has now climbed to 17. The ingredient of the soil that the wheat plant removes most and which, therefore, must be replaced in greatest quantity is nitrogen; in the provision of nitrogenous manures chemical science has already made an important contribution to life and health. In 1926 the chemical factories of the world converted 1,245,000 tons of atmospheric nitrogen into solid fertilizer, all of which went to the treatment of cultivated land; it is expected that at least half as much again will be dealt with in 1927. With regard to the increase in the yield of cultivated wheat, it has recently been discovered that chlorides have an important influence. Nitrogenous fertilizers of this kind produce a greater number of grains per head in barley than when used in other forms such as the sulphate. Again the number of heads per plant may be increased by supplying the nitrogen in the form of cyananide. Hence a combination fertilizer embodying both these principles should possess extraordinary potentialities in increasing the yield per acre. Because nitrogenous and other manures can only be absorbed by the plant when presented in a limited number of forms chemical research is being directed to the discovery of the most economical molecules to synthesize; and it now appears that they work most efficiently if due attention is paid to the requirements of the soil bacteria; these require for maximum activity that the soil should be in a certain physical condition. This condition is achieved in virgin soils by the humus, the top layer of decayed organic matter; this is progressively destroyed by cultivation and has in the past been replaced successfully. Because of the replacement of the bulk of farm animals by mechanical traction farmyard manure is becoming exceedingly scarce. Malthus remarked in his *Essay on the Principle of Population* that "cattle seem to be necessary to make that species of manure that best suits the land." But Malthus was wrong, the essential is the straw; it is in rotting this that animal manure is valuable. Obviously, chemistry should be able to provide a rotting agent. Already it has been found: research at Rothamsted has revealed a method whereby any kind of straw may be partially digested to yield an excellent top dressing ; thus yet another crop by-product will replace an animal by-product formerly considered essential.

Before and since Pharaoh's seven lean years growing plant and ripening fruit have been subject to destruction by parasites ranging in size from micro-organisms to grain-loving birds. Direct action against them is always possible, but not so invariably attended by success ; the smaller the depredator the more difficult its extermination ; and the greater chance has prevention rather than cure. Signs are not lacking that in preventive methods chemical science will find increasing employment ; principally in supplying elements to the soil to render the plant immune to parasitic depredation ; it is by attack through the plant itself that most success is obtained. Mangolds, for example, which have been heavily manured with nitrogen and unsupplied with sufficient potash, suffer from leaf spot ;

chemical correction of the deficiency will yield normal mangolds from the same land. Chemical treatment of the seed before sowing is also a successful preventive measure : wheat seed may thus be immunized against smut, a most destructive micro-organism.

Similar treatment that would render the plant poisonous to animal, and therefore human, life, obviously cannot be adopted to preserve crops against the animal depredators that may be expected to multiply at the same rate as the cultivation of crops : these will have to be warred against in much the same manner as at present ; although it is possible that, their size lending an element of sport to their chase missing from microbial hunts, they will provide an alternative to fox-hunting, ruined by lack of horses : the re-introduction of falconry may well be the outcome. Whether football enthusiasts will find summer relaxation in hawking obviously depends upon adapting the principles of greyhound racing to hawk swooping.

Evidently, then, we are already busily preparing for an increasingly intensive cultivation of the earth. Whether we shall eventually cover all the lands of the earth with crops must depend upon our skill in both irrigation and the breeding of plants to thrive in climates differing from their native habitat ; in the latter of these we have already achieved something, as in pushing the Canadian wheat belt further north, but much still remains to be done, particularly in the effect of soil upon making the plant more hardy ; irrigation, too, as Dr. Bernard Keen has shown, presents many purely chemical problems concerning the effects of evaporation and drainage upon the resulting soil. We shall probably find that tropical agriculture will be confined to such carbohydrate and fat-bearing crops as sugar, soya-bean and cotton, and that the more temperate zones will be devoted to the cultivation of carbohydrate-and protein-bearing crops like wheat ; citrus and other valuable vitaminic fruits will be grown in the sub-tropical zones that favour their growth.

The problems, when we have ploughed the whole world, will be, not to make plants grow, but to grow plants bearing the maximum of food. For, although we now modify many of Malthus' conclusions, yet population continues to expand, and, as pointed out, even were the whole world to become a garden, the multiplicity of Adams and Eves would still require to be fed. Whether food supplies would always be so restricted, or tend to restriction to the subsistence level[1] must be regarded as very doubtful. The vast improvements that may be expected through increased efficiency of both the mechanical and chemical processes connected with food may, and probably will, counteract the opposite tendency. Some day it may be necessary to strike a mean between the acreage devoted to food crops and to what may be termed utility crops, although by

[1] In a properly organized world it would presumably be something like the Voigt ration.

then improvements in by-product utilization may well render differentiation impossible.

The conjunction of the findings of dietetics and the possibilities of plant-breeding may well lead to the evolution of some grain never imagined by the wildest of prophetic fantasy. Possibly by the improvement of wheat. It provides carbohydrate, fat, protein and vitamin and it has recently been shown that cross-breeding can vary the relative amounts of these components. By the application of hybridization and Mendelian selection to wheat it is possible by the use of a parent—itself unsuitable for commercial production in one climate—(say England)—to evolve new varieties possessing one or more characteristics of great excellence from the otherwise unsatisfactory parent. An example is the introduction of Red Fyfe wheat into England in 1902 and the breeding from it of many wheats with greatly increased protein content. It will be possible to grow carbohydrate, fat, and protein on the same stalk in the correct proportions for the perfect diet, and when the whole earth is tilled and sown, that will be the ideal of the planter.

The increased utilization of the tropics to make the world a garden of fruit for the varied purposes of man involves the elimination or, perhaps more correctly, the suppression within reasonable bounds, of disease in all its insidious forms. Disease, however, is not confined to the tropics ; it is apparent in some form or another in every part of the world ; but its very universality makes easier the task of its defeat, since knowledge gained under certain conditions may be applied in others less favourable to its acquirement.

The future will inevitably witness the accomplishment of a revolution in our treatment of disease, as complete as the *bouleversement* that followed Pasteur's epoch-making discovery of the microbial nature of contagious afflictions. Because Pasteur showed each disease to be the multiplication in the body of some individual organism, medicine, taking the obvious line of direct attack, has confined its activities to the introduction into the body of preparations, vaccines, anti-bodies, and so on, calculated to poison them directly; medicine in the past has viewed disease from the standpoint of the micro-organism. Now it appears as if medicine will regard it from the point of view of the patient and instead of injecting him with anti-bodies prepared in a foreign medium, will assist him to manufacture his own anti-bodies. It obviously is the scientific method of attacking the problem: to assist the whole organism of its own accord, to set its parts in order, for the body itself to turn its equilibrium from the hydrolyses of death back to the syntheses of life. It is unlikely that we should have discovered it had we not suffered the disappointments and uncertainties by which an insufficient knowledge forced us to learn.

Building on the foundation laid by

Pasteur, we have discovered that the germs of disease, no matter of what kind—diphtheria, malaria, syphilis, or any other, as they thrive, throw off poisons, the toxins, to poison the body and change the vital equilibrium in the direction of the hydrolyses of death. These toxins are extraordinarily virulent : for example, diphtheria bacilli produce a toxin so virulent that 1-25th of a drop of it, when injected into a guinea-pig weighing 500 grams, kills it in a very short space of time; that is to say, a few germs can yield so toxic a poison that the whole internal chemical equilibrium of a mass of living tissue, 250,000 times heavier than itself, can be so upset that death ensues.

Disease having been discovered to be a bio-chemical phenomenon, chemists and pathologists have achieved between them most wonderful results in the invention of compounds to fight it : for logical reasoning and indefatigable experimentation no other activity of human thought has a parallel. Although we shall probably find in the future that their solutions were mere palliatives, yet we shall be indebted to their work for every advance we are likely to make. A path that was tried, first by Jenner on smallpox, was the infection of animals with the disease in order that they should develop in their bodies the anti-toxins to fight it; preparations of these could then be taken and injected into the blood of similarly infected patients, providing them with ready-made anti-toxins.

Both these methods have yielded significant results which, pooled, show that (a) under healthy conditions the body generates the necessary anti-toxin when attacked by disease; and that (b) the anti-toxins are peculiar to the disease, as are all catalysts, whilst (c) that illness is the stage when the body's anti-toxins have proved insufficient to resist attack completely. These are the facts that chemo-therapy will work upon in the future. The task is to discover the necessary excitant that shall stimulate the diseased body to produce its anti-toxins when disabled by disease. Already some progress has been made : the body's manufacture of anti-toxins, in all probability, is localized in a depôt from which the disease-destroying chemical is distributed as, and when, required by the blood, through the body to the site of infection. Two bio-chemists have been able, during the last few years, to form such depôts in rabbits, to protect them against syphilis, by using insoluble bismuth compounds ; such depôts heal up when no longer required. Evidently if only the suitable excitant is provided and a depôt formed, the body will cure itself.

This depôt-forming habit of the body only just correlated with disease, has, however, been recognized for some time as its method of maintaining its normal healthy functions. For these it requires the services of, and it manufactures, a number of exceedingly complex substances known as the hormones, which it makes and stores in the ductless, or to give them their bio-chemical name, the endocrine glands. These hormones are among the body's own catalysts for the syntheses of life. Although each hormone is apparently specific for certain tasks yet they are all interdependent: failure of one lowers the metabolism of the whole body and may even lead to its death, as in the case of the failure of the hormone, insulin, of the Islets of Langerhans in the pancreas, lack of which produces diabetes, a sugar poisoning of the blood, leading speedily to the poisoning and death of the whole body. So far our knowledge of the hormones is confined to only a few but already it has enabled us to banish certain types of abnormality, such as cretinism, a disease, chiefly of young children, caused by congenital absence of the thyroid gland, or by insufficiency of its secretion, resulting in stunted body and mentality, and a thick, flabby skin. Research has progressed so far that we now synthesize in the chemical factory, in quantities that, if called for, could be expanded practically illimitably, three extremely important hormones: thryoxine, the hormone of the thyroid gland; adrenaline, of the suprerenal gland, and histamine, a hormone found in the wall of the lung. Others, knowing less surely, we can nevertheless extract from similar glands of animals: a side-line of the slaughter-houses of the world is, to-day, the extraction of valuable drugs. It is, one may hope, only a matter of time before we can synthesize them all and banish every kind of abnormality, both mental and physical, from the human body. Then the path will be clear to the perfecting of the race.

Before we are in a position to achieve this, we must first learn much more about the vitamins, those elusive super-catalysts without which all the vital syntheses appear impossible. So far as we have investigated, we have found evidence of five and, because of our poverty of knowledge concerning them, we can indicate no more of their chemical composition than is embodied in the names we have given them : vitamin A, vitamin B, vitamin C, vitamin D, and vitamin E ; a vitamin X has often been found, but further experiment has always proved it identical with one of the five. We know nothing more about them than the facts, of their existence, that lack of them produces disease, and that the human body appears unable to synthesize them, or to store them for very long. Lack of A prevents growth, of B causes beri-beri and polyneuritis, of C produces scurvy, of D produces rickets, and of E impossibility of reproduction both in male and female.

So far they have entirely eluded chemical analysis, and therefore, synthesis. Vitamin D is the one hopeful exception. Its preparation can scarcely be called chemical synthesis, as it has been made, or, rather, a resultant has been obtained, giving similar effects, by exposing a complex substance, called ergosterol to irradiation by ultra-violet light. This vitamin appears to be stored in the liver, for the short time it is stored by the body ; possibly the other vitamins may be stored in the glands of the body.

In the vitamins and hormones we appear to reach up as far as we have yet been able, towards the controlling factors of life. Possibly, when we have examined them fully and prepared them, we shall be within measurable distance of a synthesis of life: perhaps not of any form of life we already know but a rudimentary cell that conceivably might, through successive ages, evolve through the same stages we ourselves have passed. Any hope there may be of synthesizing an articulated, complete, free-thinking human being must be dismissed as beyond all possible hypothesis. It is definitely impossible; the labour alone of putting the parts together, even were they made, and that *might* be possible, would be too infinitely intricate a task.

It may safely be predicted that Nature's method of maintaining the succession of the human species will remain the most economical and only practicable one, even though one may say that it will certainly be profoundly controlled and consciously guided. The possibility, however, of the parthenogenetic propagation of the human species by the surgical removal of an egg from the ovary and its subsequent fertilization and culture in synthetic media as advanced by some, particularly Mr. J. B. S. Haldane, in his *Daedalus*, takes far more for granted than is likely to be accomplished. The first essential must obviously be a thorough knowledge of all the vitamins and their influence both on mother and fœtus; and secondly, we should require a knowledge of the effects of the hormones of the mother upon the fœtus. These are not impossibilities, and were they the only factors involved the process might be considered vaguely feasible; it is rather with the consequences to the race of the results of the process that make one sceptical of its possible adoption. Mr. Haldane advances in favour of such propagation the saving of trouble, energy, and pain to individuals of both sexes, that it would bring with it and the consequent freedom it would confer on them for mental activity and inquiry. One must beg leave to doubt the possibilities of mental activity in view of our knowledge of the results of a total deprivation of gonadal activity, particularly in the male, who, presumably, would be most affected.

The chemical control of fertility will probably be the first step, since recent research indicates its government by one, or perhaps more, of the vitamins. Vitamin E has been proved essential for the growth of the mammalian embryo. Lack of Vitamin E appears to react differently in the two sexes ; in the male, if continued over a sufficient length of time, it results in the total destruction of the male gonad, or testis, which subsequent administration of it has no power to repair. In the female the consequences are not so serious, damage is reserved for the fœtus and not the gonad, since vitamin E appears to be essential for a certain hormone made by the ovary in preparation for pregnancy, and, therefore, a necessity for the growth of the fertilized germ. There should be little fear of an abuse of the power this places in our hands in view of the widespread knowledge of the importance to the whole body and to the mind of all the secretions of the body and, particularly those of the genital organs.

Further, such self-deprivation of sexual potency, one may safely conclude, would be the last act of the decadent. The knowledge does, however, provide an alternative to the methods of surgical sterilization of social undesirables that is practised by certain governments. Rather than abuse, it is likely to lead to a fuller appreciation of the needs of pregnancy and, hence, a better care for prenatal conditions.

The chemical control of sex cannot be regarded as remote even though there appears to be no indications of its introduction in the immediate future. When it is made possible, civilization may well have to confront a danger of real gravity. At present there is, and so far as history can show, there always has been, a preponderance of women; not only are more female children born, but they weather the ills of childhood better, and they live longer. The female is statistically the stronger sex, and may attempt some day to change the balance to her own social and economic advantage. Modern anthropology points to the necessity of a numerical preponderance of females for the perpetuation of a civilsation. If this natural order is reversed, either consciously or unconsciously, and not allowed to right itself in the course of time, we may well fear a decline of our race and the end of Western civilisation.

The development in the child of a full complement of hormones will be an increasingly attended care of the future. The early combat of abnormalities may, in extreme cases, take the form of chemico-surgical development in the child of its ductless glands, or it may even be found possible to stimulate dormant glands (and, in passing, it may be remarked, that infantile deficiency of a gland may turn out really to be the result of wasting through lack of stimulation of a gland dormant at birth) by administration of a specific catalytic stimulant. To prevent cretinism, for example, the giving to the young child of some form of thyroxine may be found capable of stimulating the thyroid gland to activity and initiating its normal healthy development. The pre-natal care, already mentioned as a probable future development, will be followed up during the later years of child growth. The exact machinery for achieving this is perhaps outside the chemical sphere, but it does seem that some modification of our present system of Infant Welfare Centres is more likely to be the solution provided by the future for child-rearing problems than any of the predicted systems of communal incubation which, after all, seldom go sufficiently far. Provided the child is normally healthy at birth, there seems no reason why it should not survive the first few weeks of life. It is through the remaining weeks up to the age of five years that, from statistics, care is most needed for future growth, hence, since most prospective schemes appear to provide only for a brief incubation after birth, they would not be likely to attain their objective. Thus through completer knowledge of the chemical control of the body it will become possible to evolve a physical and mental type finer than any previous generation has ever dreamed. Thus it appears that we may anticipate a great evolution not only in material things and methods but also in man himself.

Geber, the delineator of exact method, Hermes, the beckoner towards more daring synthesis, are at last beginning to enter upon their kingdom.

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