# Man's Synthetic Future[1]

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THE PRESENT UNCERTAINTIES facing the peoples of the world, and the startling discoveries in science during the past few decades, have stimulated many to prognosticate about the future. Numerous and various forecasts have been made as to national groupings, forms of government, celestial transportation, sources of food, new building materials, and modes of living. Some predict communization of the world, others that there will be internal revolutions against Communism and Fascism, bringing about the return of freedom of speech and action to all people.

William J. Hale forecast the gradual regroupings of nations into four units, each of which will embrace peoples of more or less the same biological traits, but which will not be influenced by common languages and customs. The groupings will be based on physical, chemical, and biological considerations in areas which never lack self-sufficiency of any type. The smaller nations, technologically unsuited to a future in a strictly chemical world, would have to be grouped with the greater powers, which through two centuries have shown an innate ability to advance against all opposition.

The line may not yet be forming for the first trip to the planets, but the Hayden Planetarium of the American Museum of Natural History is accepting reservations for the first interplanetary flights. The rough timetable assumes rocket ships that will reach the moon in nine and one-half hours, Mars in 75 days, and Jupiter in 666 days. This may lead to new terms in timetables when a trip is almost two years in duration. The dining compartments will necessarily be enormous in size, even if food concentrates are used, and even if it be assumed that people will require less food under gravity-free conditions. Perhaps there will be celestially anchored hot-dog stands along the way.

Some rocket engineers have boldly predicted space flights within the next decade. Many, many decades seem more likely before rocket ships will be built that will accelerate to the 25,000 miles per hour required to escape from the earth's gravity. Moreover, it is still to be determined what will happen to body functions under gravity-free conditions, and how human beings may be protected in an oxygenized, pressurized ship when the body has no weight and one can lift a sledge hammer quite as easily as a pencil. These illusions are no more astounding in our day than those of one hundred years ago when, in *Darius Green and His Flying Machine,*

> Darius was clearly of the opinion
> That the air is also man's dominion,

and J. H. Yates wrote,

> I have seen so much on my pilgrimages through my three-score years and ten
> That I wouldn't be surprised to see a railroad in the air,
> Or a Yankee in a flyin' ship a-goin' most anywhere.

Predictions of this sort do not fall within the purview of the chemist, but there is a rapidly growing number of science-fiction writers who are creating fanciful plots that may someday come true.

My remarks will be based on projecting the chemical discoveries of the past to logical achievements in the future. One hundred years ago, all materials used by man were derived directly from natural sources—plants, animals, and minerals. The chemist has, through the past six decades, so perfected his knowledge of the intricacies of molecules through physical and chemical methods that he is now able to determine the patterns in which the atoms are combined in nature's substances. Indeed he is able to assemble atoms according to his own design and thus produce many of these same substances by synthesis. Moreover, he has discovered how to create new, better, and cheaper compounds based on a knowledge of natural products.

One of the first industries transformed by chemistry was dye manufacturing, an industry that is now 99 per cent synthetic. In a second field, drugs and medicinals are over 75 per cent of synthetic origin. Natural gums and resins at present account for only 5 per cent of the 2.3 billion pounds of plastics produced in the United States last year. More than half the 500 million gallons of paint used annually are based on synthetic products. Over 50 per cent of today's rubber is synthetic, and over 20 per cent of the textiles. The field of synthetic detergents has had a phenomenal growth, until more than one billion pounds are produced annually. This figure is still well below the amount of soap consumed.

During World War I we became conscious of shortages of raw and finished materials, especially chemicals; of shortages of certain foods and of the necessity for substitutes. During World War II, and now

[1] Based on the address of the Retiring President, delivered at the Annual Meeting of the American Association for the Advancement of Science, December 28, Philadelphia, Pa.

during the rearmament period, the shortages are primarily in raw materials. We normally consider that the United States has abundant resources, yet the government lists 167 strategic items that must be imported. Stockpiling by the government of materials essential to both war and peace, but not indigenous to the U. S. or found here in less than the required quantities, has resulted in artificial price increases.

Let us consider for a moment our mineral supplies. The most widely distributed metals are iron, aluminum, magnesium, and titanium. They are available in amounts sufficient to supply the world's needs for hundreds of years. Aluminum and its alloys will continue to replace steel and other metals in even larger measure than in recent years. Magnesium, a very light metal, has found many uses, especially in alloys, but certain of its properties would appear to limit its extensive industrial application. Titanium, about which much has been heard in recent months, is fourth in abundance of all metals, and its ores are widespread over the world. It is truly the metal with an attractive future. Only half as heavy as steel, it is, in a pure state, ductile, very significantly heat- and chemical-resistant, and readily forms valuable alloys. It does not corrode even in sea water. For jet engines it is ideal. Its applications would be exceedingly numerous were it not for the cost. Titanium dioxide, a common derivative, which can be obtained readily from the native ore, is familiar as a superior white pigment for outdoor house paints and in finely divided form as a delustrant for rayon and nylon. The cheap production of pure titanium metal, however, has baffled the efforts of chemists and metallurgists for years. The annual supply of the metal has been only a few hundred tons, and it has sold at a price of $10.00–$20.00 or more per pound, thus restricting its use to items where properties are all important and cost is a small factor. But now the government is supporting the construction of plants that will provide an annual production of several thousand tons to be used primarily for military purposes. The cost of production, even on the larger scale contemplated, is likely to bring the price down to not less than $5.00 a pound, a figure much too high for general industrial application. One of the liveliest chemical problems today is the attempt to discover a cheaper way of obtaining pure titanium metal from its ores. When solved, several of the metals now considered so essential for certain steels and alloys will be in less demand.

Proved mineral deposits of all ores of less common metals, such as copper, lead, zinc, manganese, chromium, tungsten, tin, and others, would appear to have a limited life. There is, however, still much territory on earth that has not been prospected, and there still exists the possibility of mineral deposits being found deep in the earth or under lakes and seas. It has been reported that under the lakes in central Finland rich bodies of ore have recently been discovered. Perhaps the future supplies are underwater or in the frozen regions of the poles.

There is a fantastically large source of chemicals hardly touched at present in sea water. The amounts of chemicals in sea water have from time to time been published, but I venture to repeat them. A cubic mile of sea water contains 143,000,000 tons of sodium chloride, more than 300,000 tons of bromine, and over 5,000,000 tons of magnesium. A host of other metals are present in lesser amounts. When it is considered that there are over 3,000,000,000 cubic miles of sea water, the potential supply of metals and salts is staggering. At present, sea water is a source of salt in some countries and an economic source of magnesium and bromine in the United States. The future chemist and engineer will discover a practical method of recovering many of the other minerals for commercial use. Paraphrasing Longfellow—

> Would'st thou, so the chemist questioned,
> Learn the secret of the seas?
> Only those who're trained in science
> Divine the possibilities.

The use of petroleum and natural gas for fuels, and more recently as raw materials for strategic organic chemicals, has been stupendous. During the past twenty-five years, the consumption of petroleum has increased, on the average, 4 per cent a year and of natural gas 10 per cent a year. The present demand for petroleum has reached a level of 2 billion barrels a year, 30 per cent of which is employed in the manufacture of several thousand organic chemicals. The demand for natural gas is 7 billion cubic feet annually, 10 per cent of which is consumed in the chemical industry.

As of January 1951, proved reserves of petroleum had been established which, on the basis of present annual consumption, would last for fifteen years and those of natural gas twenty-six to twenty-seven years. More significant, however, is the fact that in spite of the continuous increased consumption of these products the 1951 reserves substantially exceeded those of 1950. Exhaustion of supplies has been predicted periodically for three decades, but still new reserves continue to be discovered, although with greater difficulty and at increased expense. Even if the supply in the United States decreases more rapidly than elsewhere, the reserves in foreign lands will be adequate for a long time. From 1859 to 1951, almost a century, about 41 billion barrels of oil have been produced. All this would not fill a space 1.6 cubic miles in volume. This is insignificant in relation to the total volume of oil likely still to be found in the world.

But even when the petroleum is exhausted, huge reserves of coal, oil shale, and lignite are available. By appropriate processing, the study of which is well advanced if not yet perfected, these may be converted into gasoline and related products. On the basis of present consumption, coal, oil shale, and lignite reserves would last 700 or 800 years, but allowing for difficulties of recovery and for increased demand it would appear conservative to estimate they will last for at least 200–300 years. I am willing to prophesy that when the time of exhaustion arrives scientists will have found substitutes.

Petroleum, originally a source merely of kerosene, then of gasoline and lubricating oil, has become, along with natural gas, the raw material for a host of aliphatic and aromatic chemicals upon which many of our chemical industries are founded. The magnitude can be realized best by citing that 1.25 billion pounds of butadiene, obtained by an appropriate cracking process from petroleum, are used annually for 825,000 tons of synthetic rubber. From 3,500,000,000 pounds of ethylene, propylene, butylene, and isobutylene, 16,000,000,000 pounds of derivatives are made each year. Just a decade or two ago the chemical industry relied upon coal tar, the volatile liquids obtained when coal is coked, for many of its raw materials. But with increased use of petroleum for power, and of natural gas for heating, less coal is being coked and the supply of chemicals from the coal tar is much smaller than the demand. Industry has now turned to petroleum for a substantial proportion of its chemicals for the synthesis of dyes, drugs, plastics, and fibers.

Rapid mechanization has made search for substances to produce energy as well as heat one of our prime objectives. A hundred years ago, it was wood, and now fossil fuels have the attention of a multitude of technologists. It is difficult to conceive of modern life without power and heat. In spite of the discovery from year to year of more reserves of energy-containing materials, the time before these are exhausted is at most a matter of a few hundred years and then a new source of energy must be available.

A perpetual supply of energy comes from the sun. How vast it is compared to the energy-supplying materials on earth may be realized by a comparison presented in an article by Eugene Ayres. Suppose that all the coal, lignite, peat, tar sands, crude petroleum, natural gas, and oil shale that we are likely to produce in the future on the basis of the most optimistic estimates were collected. Suppose that all the timber of the world were cut into cordwood. Moreover, suppose that all the uranium and thorium that are likely ever to be discovered were purified and made ready for nuclear fission. Suppose now that this fuel were distributed over the face of the earth, that the sun were suddenly extinguished, and that the fuel were ignited to give energy at the rate at which we are accustomed to receive it from the sun—the combustible fuel would be gone in three days. Nuclear reactions would last a few hours. The energy that actually reaches the earth from the sun is over 30,000 times that of all the fuel and water power now used. There just isn't anything that can be a competitor of the sun. It is fortunate we shall continue to have plenty of solar energy, which, directly or indirectly, serves to keep the world an attractive place in which to live.

Of the annual land vegetation, only 14 per cent is consumed as food, fuel, lumber, paper, and chemicals. The balance of 86 per cent is returned to the earth to maintain essential biological balance. With our ever-increasing population, it is doubtful whether the fuel use of vegetation can be increased to any very great extent.

Sooner or later the inexhaustible supply of energy from the sun will be used to supplement, or in large measure to replace, energy-containing materials on earth. Only limited progress has so far been made. Of the scientists' approaches for collecting the sun's energy several have shown some promise. A popular study has been that of the single-celled alga *Chlorella pyrenoidosa*. This plant multiplies at a rate that appears to be limited only by the carbon dioxide content of the water. Carbon dioxide in the air amounts to 0.03 per cent. It has been found that algae in pans of water six inches deep are capable of absorbing up to 2 per cent of the total solar energy falling on a given area as compared with less than 0.1 per cent for average agriculture. A yield of 15 dry tons per acre has been realized, which is nearly five times that of the best land growth, and scientists believe that this yield can be trebled. The Carnegie Institution has recently reported what is claimed to be the first large-scale experiments with *Chlorella*. Whether these algae may be used directly for cattle or human food, or whether they may be converted more profitably into chemicals or fuel is a problem for the future. To provide 1 billion barrels of motor fuel from algae would require an area of 35,000 square miles, assuming 35 dry tons of algae per acre could be obtained.

Photosynthesis, the process by which all vegetation is created, is not well understood. In essence, the plant converts the low-energy compounds, carbon dioxide and water, to carbohydrates and oxygen in the presence of chlorophyll. Attempts have been made to replace chlorophyll by synthetic dyes and inorganic chemicals. It has been reported that from certain experiments an amount of energy is absorbed equivalent to that absorbed in the presence of chlorophyll.

The use of glass, sometimes with reflectors, to collect the heat from the sun shows promise of becoming practical. Energy absorption seven times as efficient as the most optimistic agricultural proposals has been claimed. Apparatus is now in use for the heating of water by the sun.

Phosphors are chemicals that absorb radiant energy and radiate it after a certain length of time. Such chemicals might be employed to absorb energy from the sun during the day and for illuminating purposes at night. Even though inefficient in this process of absorption and emission, the amount of the sun's available energy is so great that this procedure is not beyond the realm of practical possibility.

New sources of energy, however important they may be, are not an immediate problem but one for future generations of chemists and engineers. With our present adequate raw materials, let us explore what discoveries may be expected. "Synthetic polymers" is a term used by the chemist for the giant molecules he has learned how to manufacture from very simple ones. Such polymers possess very different physical properties and relatively inert chemical properties compared to the substances from which they are derived. Synthetic rubber, plastics, resins, and fibers fall into this category.

Today's synthetic rubber is the equivalent of natural rubber when fabricated into tires for passenger automobiles. Many improvements in the processing of synthetic rubber for tires have been made in the past decade, the most interesting of which has been recent—the incorporation of a substantial amount of petroleum in the mix. The resulting tires are claimed to have no inferior qualities, and some superior ones, to those that are oil-free. Moreover, they can be made more cheaply, and a substantial amount of raw rubber is conserved. A synthetic rubber suitable for heavy-duty tires on trucks, buses, and other large vehicles has yet to be found. Present synthetic rubber tires when used for this purpose are susceptible to a heat build-up that leads to excessive degradation. The eventual discovery of a synthetic rubber for this purpose is merely a matter of time. Moreover, special rubbers, capable of withstanding the cold of the Arctic and the heat of the equatorial desert regions without losing the required elasticity, and those which are oil-resistant and suited for low-temperature utilization, will be added to the list.

Dozens of various kinds of plastics are now sold commercially. These vary from the clear and transparent, especially suitable for ornamental purposes or for airplane windshields, to very tough, chemical- and heat-resistant plastics for use as gaskets in chemical operations involving corrosive materials. There are resins and plastics for parts of chemical equipment; for coatings of wire to be used in the construction of small motors operating at high temperatures to produce the power of an ordinary larger motor; for the waterproofing of fabrics; for finishes of wood, metals, and even stoneware. Plastics are available for all types of bristles, and others are suitable for replacement of metals even where strength is a primary factor. The future will see transparent plastics that will not discolor and with surfaces that will not craze or scratch readily; finishes for wood and metals that will remain durable for long periods of time in the presence of sunlight and salt air; and flexible, water- and moistureproof film of any desired strength.

Cotton, silk, and wool have been the fibers used almost exclusively for fabrics until a few decades ago. Rayon and acetate silk were then introduced. These are both chemical modifications of cellulose, derived usually from cotton or wood. In spite of the fact that they lack many of the desirable properties of the natural fibers, particularly wet-strength and recoverability of the original shape upon drying, these fibers have been widely accepted and have supplemented or in part replaced cotton and silk. Acetate fabric possesses a luxurious "feel" and drapes in soft, lustrous folds. Acetate blends remarkably well with other fibers. Just recently it has been announced that a rayon has been made in which the basic structure has been so modified that the resulting product has the wet-strength exhibited by natural fibers. If this is authentic, one of the greatest steps forward in rayon manufacture since its inception will have been achieved.

About fifteen years ago nylon, a strictly synthetic fiber, made by combining very simple molecules into a complex one similar to those nature furnishes us, made its appearance. Chiefly because of its rapid-drying properties, its durability, and its resistance to fungi and insects, it has found many applications for which natural fibers are not suitable. Natural silk, for which nylon is a substitute, has never recovered its prewar status. The brilliant researches in Japan extending over a period of forty years, when the silkworm was nurtured and pampered until he produced an egg-shaped instead of peanut-shaped cocoon with a filament twice as long as formerly and of double strength, will be of no avail by the time the synthetic chemist has had a decade or more of additional experience. The uses for nylon have become so numerous that the demand cannot be met by present production facilities. Newer synthetic fibers have appeared on the market—for example, Orlon, Acrilan, Dynel, which resemble one another somewhat in properties and are all based on the same simple chemical, acrylonitrile. These fabrics are utilized particularly for seat covers, curtains, and filter cloths in industry. They are also suitable in the apparel field because of their smart appearance, long wear, and easy laundering. Still another synthetic fiber is Dacron, which resists wrinkling, water, and moths as does no other fiber. Suits made of Dacron go through rainstorms without losing their crease, and can be cleaned with soap and water without losing the original shape after drying.

Rapid drying is effected because the threads or fabric do not absorb water, and drying consists merely in the evaporation of surface moisture. But this nonabsorption of moisture leads to a certain amount of discomfort, particularly in hot weather. Consequently, closely woven fabrics for shirts and undergarments have in large measure been replaced by those with a sheer or open weave. To find a fiber that will dry rapidly and at the same time permit moisture to penetrate is asking more than the chemist is likely to discover, since they are two incompatible properties. But these synthetic fibers must be improved in other ways, or new fibers found which have the desired properties, before natural fibers will be extensively replaced. The present synthetic fibers do not take dyes as effectively as natural fibers, and up to the present it has been impossible to manufacture fabrics with the attractive colors so frequently found in silk and wool. Synthetic fibers also have the annoying property of melting or changing color if the pressing iron is too hot. The "feel" of synthetic textiles has been improved, but the resiliency of wool or the warm, soft "feel" of silk has not yet been duplicated in the synthetics. When, however, synthetic fibers are blended with wool or rayon in various proportions, fabrics with many of the desirable properties of each of the components have been obtained.

Certain representatives of the petroleum industry, when called upon to make speeches in foreign lands on the progress of petroleum chemistry, have demonstrated the achievements by clothing themselves completely—suit, necktie, shirt, underclothing, and socks—with synthetic fibers, the primary chemicals for which are all are derived from petroleum. For any traveler in foreign lands, the convenience of synthetic fiber wearing apparel is superlative.

I predict the discovery of synthetic fibers which the public will prefer for most purposes to the natural fibers. An official of the wool industry made a statement recently that the demand for wool as a fabric will never be replaced. These words were spoken by one completely unfamiliar with the potentialities of chemical research. Just as the automobile replaced the wagon, synthetic fibers will replace the natural fibers. Half the wool now consumed will be replaced by synthetic fibers within ten to twenty years, the time being dependent primarily on the restrictions which industry encounters in materials and money for plant construction. Synthetic fibers to replace cotton will also be discovered; these will be strong, durable, and moisture-absorbing, thus making them suitable and comfortable for wearing apparel. They will not, however, be rapid-drying.

The plastics to replace cotton will also serve to replace natural leather for shoe uppers. For years excellent leather substitutes, especially for seat coverings and bookbinding, have been available but not for shoes. Natural leather permits moisture to penetrate, and the feet remain dry except when it is unusually hot. The present artificial leathers do not have this property. As a consequence, when shoes of this material are worn the feet become moist and uncomfortable. With durable, moisture-absorbing plastics, the problem of synthetic shoe uppers will be solved.

Plant life is essential to human existence, and the chemist will contribute much in this field. By well-known processes of selection and plant breeding, the agriculturist has succeeded, during the forty years that soybeans have been grown in this country, in increasing the oil content from 16 or 17 per cent to 21 or 22 per cent. Hybrid seed corn, which is now widely used by farmers, results in an increase in crop yield sometimes as high as 50 per cent, essentially without any additional requirements in the soil. The inference from these achievements is that proper chemical treatment of plants could result in fundamental modification of their metabolism. By standard agricultural development methods the future will see food crops in which the size of the plant is dwarfed and the fruit, kernels, or ears of corn of greater size. In this way, more plants can be grown in a given area and the subsequent crop will be larger.

Another means of providing a greater crop from a given acreage is by plant-growth stimulants—chemicals that accelerate the growth and maturation of plants. Several are known, and chemists will discover new and better ones, with the eventual result that two crops of the same or different plants may be grown during the normal season where now only one crop is possible. Perhaps during these experiments we may find substances that will not merely speed up the growth of a plant but cause its fruit to be larger—for example, pears, apples, or oranges the size of grapefruit. If this seems fantastic, just consider the coconut milk factor recently discovered in academic experiments. On its addition to a basal nutrient agar medium, mature plant cells are caused to subdivide; for example, cylindrical slices of carrot will grow rapidly.

Plant physiology is still in its infancy, and it must be better understood before rapid advancement in the cultivation and control of plants can reach a maximum. Experiments performed in Germany during the past ten years permit one to envisage remarkable achievements in the future. In the flowers of the forsythia, those early yellow blooms which decorate gardens in many parts of the country in the early spring, it has been observed that the pollen of one flower never fertilizes the stigma of the same flower, nor does it fertilize a flower of the same type whether the flower is on the same or another bush. Formation of seed occurs in flowers where the pollen comes from long stamens and is accepted by flowers with long stigmas. Similarly, pollen from flowers with short stamens fertilizes flowers with short stigmas. Other combinations result in nonfertilization. A chemical study of pollen from long and short stamens has revealed that, although closely related chemicals are in each, they are actually different. With this discovery, a procedure was developed whereby fertilization of these flowers could be made to occur by chemical treatment where it would not have occurred naturally.

Not too remote from these experiments is that of spraying the blossoms of tomato plants with 2,4-D, a chemical commonly used for killing broad-leaved plants. This not only causes many more of the earlier blooms to mature into fruit, but the tomatoes formed are seedless. With this start, let us look forward to seedless raspberries, blackberries, cranberries, and perhaps many other kinds of fruits, such as watermelons, pears, and apples.

One of the banes of the farmer or the florist is the insect pests that either destroy or greatly reduce his crops. The varieties of insects and mites are many, and consequently different kinds of chemicals have been sought to eliminate them. DDT is effective in the killing of flies, mosquitoes, and many insects that attack plants, but it is not universally good. Several other insecticides are available, each with its special properties for use on a certain type of insect. Periodic spraying of crops, however, is not only expensive but inefficient, since it is impossible to reach all parts of the plant. The chemist must search for a more ideal insecticide. The ultimate will be a chemical, repellent to all insects and mites and innocuous to plants and to higher animals, a substance which when sprayed on the leaves will be absorbed and completely translocated by means of the plant juices. Why not seek also a combination of minerals and fertilizer required as plant food that can be absorbed through the leaves rather than to follow the traditional custom of fertilizing the soil with chemicals, a large proportion of which is washed away by the rain before plant absorption has occurred?

The farmer also requires chemicals to control weeds and to simplify his cultivation problems. Rapid advances have been made in this area, and many chemicals are known that are toxic to certain kinds of vegetation. Chemicals will sometime be available to sterilize the soil completely toward grasses and weeds but not toward the desired crop. Because of the similarity of many plants to each other, it may be necessary to provide a series of chemicals, each of which will effectively kill just one kind of several closely related plants. The layman will welcome the day when he can effectively kill the crab grass in his bluegrass lawn.

Far more important information will eventually result from the study of plants. Each plant, with the aid of the sun's energy, converts carbon dioxide and water in presence of mineral salts into a wide variety of chemicals, such as starch, cellulose, protein, vegetable oils, chlorophyll, and many other complex organic molecules in smaller amounts. These reactions take place at ordinary temperatures under very mild conditions, commonly known as "biological conditions." In comparison, the chemist is a clumsy operator. He requires massive equipment, often high temperatures and pressures, skillful engineering, and a number of operations to achieve what the plant does with a little sunlight and the simplest of chemicals. The chemist has discovered a few reactions that take place under very mild conditions and result in the formation of complex molecules from several simple ones. But he is a long way from understanding how nature operates. When, a few centuries hence, such reactions can be duplicated in the laboratory our present production methods for many organic chemicals, ingenious and skillful as they now appear, will look archaic.

Characteristic of each plant is its ability always to build up the same chemicals year after year. It has been observed, however, that if a plant is moved to a different climate the relative amounts of the chemicals present may often be modified. The day will come when a plant, after treatment with a certain chemical, will be inhibited from synthesizing one or more of the substances normally found within its structure or, on the other hand, the plant may be stimulated to create one or more of its chemicals in much larger amounts. Thus fodder crops might result from plants which now contain some toxic constituent, or plants which contain physiologically active medicinal substances may be induced to produce them in larger quantities.

The present food supply of the world, if properly distributed, would be adequate. With the steady increase in population, sooner or later all the arable land will be utilized, and even intensive farming of the soil through improved agricultural methods, plant stimulants, weed-controlling agents, pesticides, and other developments will not meet the world's food requirements. The resources of the sea will then be more intensively exploited than at present. Fish is a valuable food of high protein and rich vitamin content. It can be expanded to supplement meat supply. I envisage a more systematic fishing industry than at present—certain types of fish ranches—large fenced-off water areas in which fish are grown, fed, and annually harvested—analogous to cattle ranches.

Sea farming will be a term comparable to land farming. Marine plants for food, fuel, or chemical use will be grown and harvested like land crops instead of the present system of collecting what happens to be washed ashore. When, with these extensions, the food supplies reach the limit the chemist will provide antifertility compounds which upon addition to the diet will assure a means of controlling the birth rate.

The diets of humans have been improved until now many ailments resulting from diet deficiencies are well understood and have largely been overcome either by balancing or supplementing the food intake. Concentrated or synthetic foods containing just the necessary constituents for human growth and development are feasible, but they will never be accepted by persons in good health as long as eating attractive food is the most general and universally liked human activity. In spite of properly adjusted diets, the human race is susceptible to a long list of bacterial, virus, fungus, and degenerative diseases, some of which have thus far resisted the efforts of science.

Until half a century ago, medicinal products for treatment of disease were confined chiefly to plant or animal extracts or principles discovered originally through the cut-and-try methods of the physicians of earlier ages. The chemist has now synthesized many of these principles and on the basis of this knowledge has been able to produce other products superior to the natural. Drugs that have not been derived from the basic information provided by nature have been fortuitous or have been discovered usually by serendipity, a combination of skillful observation and chance that leads so often during scientific research to unexpected achievements of basic or applied importance.

Even though a marvelous array of drugs is now available, and a vast storehouse of information has been collected, the laws of chemotherapy are still unrevealed and decades will pass before a rational chemical basis will be provided for discovery of new therapeutic agents. The knowledge of the living cell in which the chemical reactions are constantly occurring to provide the life process is still very meager. However, the elaborate series and combinations of reactions in the cell are gradually being untangled. The cell functions in health and disease will sooner or later be clarified.

While these more basic explorations are progressing, search for more effective drugs by present procedures will be intensified. New and better drugs for combatting bacterial diseases may be expected. I envisage the gradual replacement of the drugs which must be administered intravenously or intramuscularly by others of equal or greater potency which may be taken orally. Many of the most stubborn diseases of mankind are those caused by viruses, such as the common cold, poliomyelitis, spinal meningitis, influenza, virus pneumonia, mumps, and measles. Satisfactory drugs for their treatment are lacking. The retarded progress in this field in contrast to that made in the study of bacterial diseases is the result of the absence of suitable laboratory or animal assay methods for determining the effectiveness of any chemical agent upon a particular virus. Bacteria can be grown in the laboratory, but viruses propagate only within living bacteria or living cells. Research in the next decades will solve the vexing problem of finding viricides, and thus open a new chapter in medical therapy.

For the degenerative diseases, such as cancer, heart disease, or arteriosclerosis, it is unlikely that complete cures can be found, but the organic chemist will succeed in providing products that will eliminate susceptibility toward these diseases.

As the physiology of the cell becomes better known, and the relation of chemical structure to cell and tissue is revealed, chemically induced mutation of cells may become possible. Certain hormones and other drugs are now known which affect the physical being as well as the mental attitude of an individual. The future may bring to us a series of drugs that will permit deliberate molding of a person, mentally and physically. When this day arrives the problems of control of such chemicals will be of concern to all. They would present dire potentialities in the hands of an unscrupulous dictator.

What may we expect from atomic energy and radioactive substances? The ores of uranium and thorium are found in only limited quantities on this earth. The industrial applications of atomic energy are, therefore, likely to be limited to special situations, such as submarine propulsion or power units to be used in isolated spots, inaccessible to the ordinary energy-bearing materials. Radioactive substances will continue to find more and more utilization in elucidation of organic and physiological reactions, particularly metabolic degradations and transformations. Whereas biochemical studies will probably lead to compounds which may go far toward the prevention of cancer, the newer $\alpha$-, $\beta$-, and $\gamma$-radiations from radioisotopes are likely to be found more effective for reducing or arresting growth of certain types of tumors than the older radium radiation. Promising results have been obtained by introducing such a substance as radioactive gold directly by mechanical means into certain tumors. In the diagnostic field many applications of radioactive substances may be anticipated. Thus it is now possible to demonstrate the presence of a tumor in the brain, and even to localize it accurately from outside the skull by means of certain radioactive iodine-tagged chemicals.

In 1780, Benjamin Franklin, in a letter to Joseph Priestley, wrote as follows:

> The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter. We may perhaps learn to deprive large masses of their gravity, and give them absolute levity, for the sake of easy transport. Agriculture may diminish its labor and double its produce; all diseases may be by sure means prevented or cured, not excepting even that of age, and our lives lengthened at pleasure even beyond the antediluvian standard. O that moral science were in a fair way of improvement, that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity.

Let us see what has happened during the 170 years since this was written. We do not know yet how to eliminate gravity so as to facilitate transport. In agriculture, however, Franklin's predictions have already come true. When this country was founded, it took nine people on the farm to feed themselves plus one city dweller. Today, in contrast, one man on the farm feeds himself, four city people, and one person overseas.

There can be no complaint about the achievements in treatment of many diseases by use of various serums, vaccines, hormones, vitamins, antibiotics, antihistamines, and a host of others. The life expectancy of a child has increased from fifty years in 1900 to sixty-eight years at the present time. With these results already recorded, Franklin's predictions, which relate to 830 years hence, will in large measure be correct.

Pictures of the past show log cabins, sailing frigates, oil lamps, caravans, and prairie schooners, crude utensils, hand weaving, and the man with the hoe cultivating the fields. Today life is mechanized, electrified, abundant, easy, because of the push-button era. In the future citizens will more effectively farm the land and the seas; obtain necessary minerals from the oceans; clothe themselves from coal and oil; keep themselves warm by using the stored energy of the sun; be cured of any ailments by a variety of drugs and medicinals; be happy, healthy and kittenish at one hundred years of age; and perhaps attend interplanetary football matches in the Rose Bowl.