Section B.—CHEMISTRY, GEOLOGY, METALLURGY, MINERALOGY, AND GEOGRAPHY.

President of the Section:—H. H. Green, D.Sc., F.C.S.

WEDNESDAY, JULY 9.

The President delivered the following address:—

MODERN CHEMISTRY.

One of the most characteristic features of the development of modern Chemistry is the steadily growing tendency to subdivide. Of recent years this tendency has been so marked that the various offspring of the mother science have taken on the aspects of new sciences, and the time has come when no chemist can lay claim to anything like a complete grasp of the subject to which he owes his name. This process of fission is inevitable and has its origin in the nature of the science itself. Being a basic science, like Mathematics and Physics, it enters into every department of human activity, and it has become a platitude to say that the chemist has all Nature for his province. Like Mathematics, the science might take for its ideal the compression of the Universe into an equation; with God, mayhap, as only arbitrary variable.

The field of Chemistry is so wide, and the mass of detail so enormous, that no single brain can hope to do more than grasp the underlying principles and methods of the science as a whole, and make itself master of a comparatively small corner. Specialisation has therefore proceeded, particularly in research, to an extraordinary extent; and the ramifications of the subject are so complicated that most people have only the haziest notion of the meaning of the word "chemist."

To the altogether uneducated, the term "chemist" is synonymous with that of "pharmacist" or "druggist," and, indeed, the vendors of stuffs in bottles, compounders of the decoctions prescribed by those skilled in the black art of medicine, have claimed the word for their own. Indeed, so far at one time did the term fix itself in common speech that it passed into legislative use, and, as Sir William Tilden points out, "if Sir Humphry Davy himself were now living he could not legally call himself a chemist, his name not being on the pharmaceutical register. Other lands are more discriminating in their speech—Germany using the word "apotheker," and France the word "pharmacien," as corresponding to our seldom-used "pharmacist." Far be it from any chemist mind to decry the calling of pharmacy. Properly qualified pharmacists are proud of the term, since it corresponds to a calling with a definitely recognised, legally protected diploma, and one in which it is now possible to take a university degree. Be it only emphasised that it is more allied to the medical science of pharmacology than to the abstract science of pure Chemistry, whose devotees rarely happen to be qualified to take a place on the pharmaceutical register. It is as much to the interest of the pharmacist as of the chemist to separate the two terms. The confusion, however, will doubtless last a few years longer, although it involves bad English and worse sense.

To the somewhat better educated, a chemist means a man who "analyses things." This confusion is not quite so reprehensible, since analytical chemistry is a branch of Chemistry proper, and some dignity is graciously accorded to it—saving word "analytical," which, like the blessed word Mesopotamia in the Bible, has a fascination for some minds.

To the well-educated along old-fashioned lines, Chemistry is a science which they learned all about in their first year at college; something they have forgotten.

To the *properly* educated, Chemistry is a science underlying all knowledge of material things, and providing the armoury of all other sciences, professions, arts, and trades; is one of the three basic sciences of Natural Philosophy. In his introduction to that admirable series of essays, "Science and the Nation," issued by the Cambridge Press, Lord Moulton takes occasion to point out that "in such a presentation it was inevitable that Chemistry should take the first place."

The war has done much to open the conservative British mind, and the national importance of Chemistry is more clearly recognised. There is no doubt that a new era in dignity has dawned for the chemist, and that the significance of his work will quickly filter down to the voter and up to the politician. To the discriminating he has never lacked in dignity; nor even to the thoughtless, when he turned his science into trade and made tracks for the Upper House.

But to return to the fission of our science.

At the beginning of the last century Chemistry was divided into two main branches, "Inorganic," which dealt with metals and minerals, and "Organic," which concerned itself with compounds of animal or vegetable origin. In 1828 the famous research of Wöhler, resulting in the conversion of ammonium cyanate, which had been prepared from wholly inorganic sources, into urea, which had hitherto only been known as a product of vital action, smashed the arbitrary distinction between "organic" and "inorganic," and reunited the breaking science. The reunion, however, was of very brief duration, since in following up the ideas involved in the first organic synthesis it was found that the number of derivatives of the one element, Carbon, far exceeded all the other derivatives of all other elements put together, and it soon became evident that a fresh division into carbon and non-carbon compounds had to be made. Since Carbon was the most characteristic element of the old "organic compounds," the old term was revived, and "Organic Chemistry" became the "Chemistry of the Carbon Compounds." The number of such compounds now actually described is somewhere about one hundred and fifty thousand, and new members are being added to the list every day. The number theoretically predictable is a question only of permutations.

Since they are of extraordinary complexity, no chemist, professed organic chemist though he be, makes the least attempt to remember, or deal with, anything more than a mere fraction of them; but contents himself with type compounds and a study of the underlying principles involved in their preparation or synthesis, the determination of their constitution, their sources, properties, and the uses to which they can be put. To attempt to memorise the way in which the constitution of them all has been determined would be as stupid as to attempt to memorise a few thousand games of chess. Obviously, it is only possible to learn the principles of the game.

The domain of the organic chemist is so wide, and the problems he may have to tackle are so intricate, that the modern investigator usually finds it necessary to confine himself to a very small section of his branch science, ogle the amino-acids, give his heart to a heterocyclic ring, or soak his brain in an aniline dye. But if he does any of these things he becomes a very useful person.

As an illustration of the significance of Organic Chemistry in our daily affairs, the chemistry of coal-tar may be taken.

In the early days of coal-distillation the only products arrived at were illuminating gas and coke, the bye-product, tar, being regarded as of little value. Various chemists then took up the study of coal-tar, at first in the spirit of "pure research," and at the present day the commercial value of the tar products far exceeds that of the illuminating gas itself. These products are so numerous and so important that it is impossible to offer even the briefest sketch of them here. Suffice it that huge industries have arisen from the first academic researches, and that the products go to feed all the other arts and sciences. To the doctor go his anæsthetics, his hypnotics, his febrifuges, and his specific drugs like salvarsan; to the biologist his stains and solvents, and to the dyer his dyes; to the soldier his explosives; to the photographer his developers; to everyone, directly or indirectly, something. It would be difficult to estimate the value to the community of the labours of the early organic chemists, to whom the coal-tar industry owes its origin, though some idea of it may be obtained when it is considered that before the war Germany exported over ten million pounds' worth of coal-tar dyes alone per annum. It may not, perhaps, come amiss to point out that the first step in the sequence of development was made in Britain in 1856, when Sir W. H. Perkin, then a boy of eighteen, was carrying out a research with a totally different object in view—a research into Quinine. In the course of his work he obtained a substance which "seemed worthy of further investigation." Being a scientist and not a utilitarian, he did not throw it away, but instituted further research. It turned out to be a dye-stuff, "Aniline Mauve," or "Tyrian Purple." Further investigation paved the way for similar synthetic products. This came just at a time when the chemistry of coal-tar was being developed, and since Benzene was the basis of Perkin's dye, the way was clear for the commercial exploitation of his discoveries. Indeed, the youthful Perkin turned sufficiently utilitarian to start a factory at Greenford Green, although his heart was always in research, and in 1874, at the age of 36, he retired from business as a manufacturer to devote himself exclusively to the pursuit of knowledge for its own sake. It is of interest to remember that until 1870 Perkin's works were the only producers of artificial Alizarin.

At the time of Perkin's discoveries Britain was the greatest producer of coal-tar, and was pre-eminent in the dyeing industry. Six years after the discovery of "Aniline Mauve," Hofmann, a a German, wrote in his report on the London Exhibition of 1862:—

"England will, beyond question, at no distant date, become herself the greatest colour-producing country in the world; nay, by the strangest of revolutions, she may, ere long, send her coal-derived blues to indigo-growing India, her tar-distilled crimsons to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and other countries whence these articles are now derived."

It may well be asked why English manufacturers, with exhibits in frames under their noses, and prophecies such as Hofmann's before them, did not avail themselves of their opportunities, and why England has fallen from her premier position in the world of chemical industry. Two causes for the decline are apparent: firstly, the neglect of organic chemistry in the Universities, and, secondly, the total indifference of manufacturers to the practice of research in connection with their own processes. The period belonged to the dark ages of compulsory Greek, when the Professor of Chemistry at Cambridge was a country clergyman, who nobly came up once a year to give a course of lectures; when, as Tilden remarks, it was thought very creditable on his part to do so much.

Perkin himself, Meldola, Green, and numerous other English chemists, raised their voices in vain against the national neglect of chemistry. The neglect continued, and by the early eighties Germany had gained control of the infant industry. And not only of this industry, for the highly trained research chemists engaged in the laboratory investigation on synthetic dyes developed other lines of research, so that on the outbreak of war Germany had practically the whole trade of the "fine chemicals" (highly priced, finished products) in her hands: a trade so vast that the *export value* was estimated by Professor Grossman, of Berlin, at *ninety-seven and a half million pounds per annum*.

Fortunately, the day of neglect is well-nigh over in Britain, and there is a chance that part, at least, of the trade in dye-stuffs and fine chemicals will "come home." Shortly after the outbreak of war, when the dye-houses of Yorkshire and Lancashire were almost at a standstill, and a textile industry worth 200 million pounds per annum was embarrassed for the lack of about one million pounds' worth of dye-stuffs, the Government assigned a million sterling to an attempt to resuscitate the production of synthetic dyes, and to provision for research into the making of colours from coal-tar hydrocarbons. Further large endowments for general research are promised, and it is being recognized that "scientific research" is a matter for the State as well as for private enterprise. It may be mentioned in passing that the *natural indigo* industry is not necessarily past redemption. Germany's export trade in synthetic indigo rose to about two million sterling in 1913, while the area under cultivation of indigo in India fell from one and a half million acres in 1897 to less than a quarter of a million acres in 1913. But it is not impossible that a little money spent on chemical and botanical research in relation to agriculture might turn the tide, and put the natural indigo in the position to smash up the synthetic industry. It must not be forgotten how Germany built up her trade in sugar from beet, and the important part played by the breeding of high-sugar roots, and the utilisation of waste products of the sugar factories.

Leaving now the domain of Organic Chemistry, we may consider Inorganic Chemistry, or the chemistry of the non-carbon compounds. This branch of chemistry is also an enormously wide one, and concerns an enormous number of compounds—all the compounds of some ninty odd elements. Every chemist must, of course, have a thorough grounding in inorganic chemistry; but, again, no modern chemist professes to cover in detail the whole field. The modern investigator or practitioner finds it necessary to limit himself, after his broad general training in all branches of chemistry, to some one section. He may, for instance, devote his attention to the chemistry of metals, and become a "metallurgist"; to that of minerals, and become a "mineral chemist," or to any other section, and label himself with an appropriate name. Inorganic chemical processes underlie so many of our industries that it is impossible to enumerate them here; the production of the metals, including gold; of steel and special alloys; of the gigantic alkali and acid requirements; of artificial manures; of incandescent mantles; of a thousand and one articles of every-day use.

The third big sub-division of Chemistry is "Physical Chemistry," a section of the science overlapping into physics. It includes what is termed "chemical statics" and "chemical dynamics," and the relationship between chemical properties and physical properties; position of equilibria in chemical reaction, speed of chemical reaction, and influence of mass as well as of chemical structure of reacting materials, optical and electrical properties of substances, ultimate constitution of matter, and so forth. It lies at the root of all chemical theory, whatever branch of chemistry be considered. The Haber process, upon which Germany depended for her nitrogen supply during the war, is a technical triumph of physical chemistry.

Physical Chemistry is, again, a section so wide, that although in the sense now used it is a product of the last quarter of a century, it is itself rapidly undergoing division. The separate science of "radio-activity" has already split off as a fission-product of very recent growth, but which in the last few years has contributed enormously to basic chemical theory and an understanding of the ultimate constitution of matter, and which is rapidly assuming great practical importance. "Metallography" is a section of physical chemistry which can also be treated as a branch of Metallurgy. It deals with the relation of the micro-structure of metals and their alloys, to their physical properties. It is a very young science, but it is already of enormous industrial importance. One of its recent achievements is the production, for aeroplane purposes, of an alloy which, weight for weight, is more than twice as strong as steel. Other fission-products of physical chemistry are rapidly developing, and it will not be long before "Colloidal Chemistry" attains the dignity of a separate science.

These three main sections, Inorganic, Organic, and Physical, represent the three primary lines of cleavage of the science of Chemistry. Analytical Chemistry, though to some extent it is taught as a separate science, and is practised as a separate profession, can hardly be called a distinct section of chemistry, since every chemist must be an analyst, and every analyst entitled to the name must be a sound general chemist with a training in all three sections of his science.

For Chemistry as a whole the sister science of Physics is absolutely essential, as also a working knowledge of Mathematics. For the higher reaches of Physical Chemistry the investigator must be a mathematician of no mean order.

These three major branches of chemistry are taught by separate professors in all properly equipped colleges, with sub-sections taught either by separate professors or by specialist lecturers, according to the purpose for which the institution exists, and its financial resources. Thus in the University of Illinois the chemical department proper is organised under seven divisions, with the following staff:—

General Chemistry and Qualitative Analysis.

1 Professor.	3 Instructors.
1 Assistant Professor.	8 Assistants.
1 Associate.	19 Graduate Assistants.

Quantitative Analysis and Food Chemistry.

1 Assistant Professor.	1 Instructor.
1 Associate.	7 Assistants.

Organic Chemistry.

1 Professor.	3 Assistants.
1 Assistant Professor.	1 Graduate Assistant.
1 Instructor.	

Physical Chemistry and Electro-Chemistry

1 Professor.	1 Instructor.
1 Associate.	1 Assistant.

Physiological Chemistry.

1 Professor.	1 Assistant.
1 Lecturer.	

Industrial Chemistry.

1 Professor.	1 Instructor.
1 Assistant Professor.	1 Assistant.

Water Analysis and Sanitary Chemistry.

1 Professor.	1 Instructor.

In addition to this staff of 60, there are 2 research assistants, 6 fellows, several graduate scholars, 1 glass-blower, 1 mechanician, 1 clerk, 2 stenographers, 1 lecture assistant, 4 storekeepers and laboratory helpers.

This, it may be further added, is only the general chemical department proper, and does not include the chemical staff of applied departments, such as the Faculty of Agriculture, which has its own professors and lecturers.

The Chemical Department of the Imperial College of Science and Technology, South Kensington, London, is staffed as follows:—

1 Professor of General Chemistry.
1 Professor of Organic Chemistry.
1 Professor of Physical Chemistry.
1 Assistant Professor.
1 Lecturer.
5 Demonstrators.
4 Assistant Demonstrators.
1 Research Assistant.
1 Professor of Chemical Technology.
1 Associate Professor.
1 Lecturer in Chemical Engineering.
1 Lecturer on Refractory Materials.
2 Demonstrators.

This, again, is the department of chemistry proper, and does not include Metallurgy, which has a department of its own, or Biochemistry, which is attached to a different department of the College.

The elaborate staffs shown here, merely for the teaching of one subject in its main aspects, give an indication of the way in which the division of the science has proceeded. It may be added that applied departments, which take their title from the "group course" they teach, frequently appoint their own chemists separate from the department of chemistry proper. Thus the Medical Faculty in the Univeristy of Edinburgh has just appointed a professor of "Medical Chemistry," whose duty it will presumably be to arrange a compact course specially arranged for medical requirements. The University of Glasgow has just created a chair of "Physiological Chemistry," in which a section of chemistry will be taught as applied to general Biology —for students of medicine, pure science, and chemical technology.

Faculties of Agriculture also have their own professors of "Agricultural Chemistry," and in big American centres sub-sections, such as "soil chemistry," "dairy chemistry," and so forth, are handled by specialist lecturers.

This reference to specialisation in chemistry, in directions other than sub-sections of the pure science, brings us to the second aspect of the process of fission.

It will be quite obvious by this time that there is no such thing as the "Compleat Chemist." The chemist has all Nature for his province, and all Nature is too big a morsel for mortal man to chew. Fission is inherent in the nature of the science and cannot be avoided, and when it gets down to bed-rock it is the specialised man nowadays who does the really scientific work.

Knowing this, it might be imagined that the science must of necessity drift to a specialisation so intense that its own broad problems suffer neglect; that the individual worker could never remain broad enough to visualise the main outlines of the practical application of his own subject; that he would not see the wood for the trees. This idea, however, is altogether erroneous, although it may perhaps have something to do with the pre-war British idea that the scientific specialist should be subordinate to the man of "broad" training, guaranteed to absorb the wood as a whole, and resolutely refuse to believe in the existence of the trees; guaranteed to fulfil the Euclidean conception of a plane—length and breadth without depth. It has taken a world-war to make the politico-legal mind realise that the very process of specialisation gives a fresh kind of breadth; a capacity for focussing details to a specific end. The English organic chemists, monomaniacs moaning over the constitution of the benzene ring, cried in the wilderness for 40 years before their country woke up to the fact that vital industries turned upon the question as to whether Kekulé, Claus, Ladenburg, or Armstrong, had been right in their conjectures concerning the configuration of the aromatic nucleus. In the hour of tribulation many men, "finding out" as Moulton described Pope, "how in the extremely quiet and domestic circle of crystals the various molecules sat round the table," were called in to remedy the neglect of half a century. That, it may be added parenthetically, is the modest even-tempered genius of English administration—the capacity to rectify her blunders at the eleventh hour . . . even if she has to call an occasional Welshman or Scotchman to the rescue!

It must therefore (irrespective of the parenthesis!) be emphasised that the movement towards specialisation in chemistry is only one side of the question of "broad outlines" and "practical propositions." In the very process of specialisation chemistry is widening its sphere of usefulness, throwing out tentacles to grasp a whole range of subjects, which were formerly regarded as quite beyond the sphere of chemical handling, and which even yet only the chemist recognises as belonging to his proper province. It is true that it is rapidly becoming fashionable for every institution to have its "own chemist," but it is not so sure that every institution knows what to do with him when it's got him. At the present moment administrative departmental heads are in process of catching tartars—troublesome people who insist upon having a "different kind" of breadth of outlook, and want to do things which look very unremunerative.

To illustrate the way in which the highly specialised science throws out its tentacles to the other sciences and broadens the outlook of civilisation, a few concrete examples may be taken. Going first to the subject of Astronomy, which to the non-scientific mind would appear to be as untainted of chemistry as could be desired, a connecting link is at once provided by physical chemistry and its spectroscope, by means of which it is possible to analyse substances which cannot be handled, but from which light is available, and by means of which it is possible to do such odd things as calculate the speed of a star.

When a beam of complex light is passed through the prism of a spectroscope the light waves are differentially diffracted, so that each wave-length can be examined separately. The range of the rainbow colours in the visible spectrum corresponds to wave-lengths of one hundred-thousandth part of an inch at the violet end, to three hundred-thousandths of an inch at the red end, but since the range of wave-lengths capable of affecting silver salts is wider than that to which the human eye is sensitive, it is possible to photograph the ultra-violet or "invisible light," and so extend the range of spectroscopic analysis. Spectroscopic examination of a substance may be direct, by its so-called "emission spectrum," or indirect, by its so-called "absorption spectrum," *i.e.*, the spectrum obtained by allowing light which produces a continuous spectrum to pass through the substance to be examined before entering the spectroscope. In the former case a series of spectral bands, of colour if the wave-lengths all fall within the range of the eye, is obtained. In the latter a series of black "absorption bands," characteristic of the substance, is produced. Each element, in the condition of vapour, has its own characteristic spectrum, and since the spectra of the known elements are known, it is possible to identify the lines of characteristic elements present in bodies emitting light of their own, or present in vapours through which light passes. The delicacy of spectroscopic analysis is very great, and it is possible, for instance, to detect one part of sodium vapour in twenty thousand million parts of air.

By turning the telescopic spectroscope on to the stars it has been shown that, although most of the well-known elements are there, some elements are present (unknown bands) which have not yet been discovered on the Earth, and have never been handled in our laboratories. The element Helium, which has recently become of great theoretical importance, and will be of great economic importance if it can be obtained in sufficient quantity, was first detected in the sun and actually named before it was discovered on the Earth. By studying the absorption bands in the solar spectrum the atmosphere of the Sun has been studied, and the presence of about 40 terrestial elements discovered.

By applying the telescopic spectroscope in another way it is possible to determine a "velocity" instead of a substance, and to determine the speed of stars moving in the line of sight. This is done by accurately comparing the position of certain lines produced by elements in the star with the position of the lines produced by the same elements in the neighbourhood of the spectroscope. Thus, for instance, if the hydrogen or iron line of a star is nearer the violet end of the spectrum than it should be, the star is coming towards us; if nearer the red end, the star is travelling away from us. By photographing stellar and terrestrial spectra of the same element on the same plate, and measuring the deviation with a microscope, it is possible to calculate the approximate speed at which Star and Earth are approaching to, or receding from, each other.

What is really being done is to measure the frequency of the waves of light from the star, since the position of any line in the spectrum is conditioned by this. A rough analogy which has been used to explain the process to the lay mind, is offered by the consideration of a person standing on the seashore with the waves breaking over his feet at a steady rate—so many per minute. If he now walks into the sea, he will encounter more waves per minute, and the faster he moves the more frequently will the waves appear to break over him. If he then walks back to the shore, the waves will appear to come more slowly and fewer will break over him in any given time. In reality the waves are coming at the same rate all the time, but by measuring the frequency with which they appear to come to him he could calculate the rate at which he was walking. In the same way, by measuring the deviation of frequency of the light waves coming from a particular element in a star, from the known frequency on the Earth, or, in other words, measuring the displacement of its spectral lines, the speed of the star in the line of sight can be calculated.

It may be mentioned, as of local personal interest, that Dr. Lunt, of the Cape Observatory, is a chemist turned astronomer, lured first by the connecting link of the spectroscope. Mr. H. E. Wood, of the Johannesburg Observatory, one of our vice-presidents last year, is a physicist turned astronomer.

As an illustration of the application of Chemistry to Geology, the work of van 't Hoff on the salt deposits at Stassfort, East Prussia, may be cited. These salt beds, best known from their enormous economic importance as major source of the world's supply of Potash, have been shown, largely by chemico-geological methods, to have been formed by the gradual drying up of an inland sea, the various salts now found being deposited at varying temperature and concentration in accordance with the laws governing ionic equilibrium in solution. Van 't Hoff, from the elaborate data acquired in his work on the chemical compounds occurring in the Stassfort beds, was able to show that certain of these were only capable of simultaneous deposition within narrow limits of temperature. Thus from the presence of Glauber's salt and Astrakanite in the same stratum, he could fix the temperature at which that stratum was laid down as between 4.5°C and 18°C. Other sensitive compounds defined still narrower limits, in some cases giving upper and lower ranges to within half a degree, and by skilful interpretation of chemical data it became possible to determine very accurately the actual temperatures, and nature of seasonal variation, under which the various strata were deposited; thus affording invaluable information to the geologist concerning conditions maintaining millions of years ago. As for the present day, the utilisation of these beds, with their output of thirteen million tons of potash salts per annum, demands the services of the trained chemist at every turn, while the ramifications of the industries dependent upon them brings in highly specialised sections of chemistry in all directions. Their use in agriculture has been associated with the budding of pure chemistry into "agricultural chemistry"—in which connection it may be pointed out that far and away the greater part of the basic work upon which scientific agriculture turns, is due to chemists and botanists who succumbed to the fission of their sciences.

The development of Agricultural Science is too long a story to tell here, but the dominant part played by chemists is reflected in the personnel of institutions devoted to agricultural research. At Rothamsted, for instance, the succession of directors has been a succession of able chemists. That, in the opinion of competent agricultural authorities, specialisation in applied sciences should still follow the natural cleavage line of fission from the pure sciences, is clearly indicated by the recent "Memorandum on the Reconstruction of Agricultural Education in England and Wales," published by the Agrciultural Education Association. Paragraph 65 runs: "For the 'scientific specialist' class of student we would recommend the Honours Degree courses in pure science, rather than the agricultural degree course, as the normal avenue of approach to specialisation, with the addition of a post-graduate course in agricultural science. The agricultural degree course may be made to serve as preliminary training for specialisation, though *not as satisfactorily*, if *supplemented* for this purpose by a full post-graduate course of Honours' standard in pure science. One year's practical training on a farm is a most desirable part of the education of such a specialist."

It may be added that for general agriculturalists, such as county advisers, non-specialised teachers, and those following general agriculture as a profession, the reverse mode of education is regarded as satisfactory; a general diploma or degree course, embodying the general applications of the sciences.

This emphasis on "pure science first." for the research worker, is a hopeful sign for education; is presumably made with the idea of inculcating the *method and principles* of science before allowing the student mind to be fuddled in the cloud of empiricism, which of dire necessity is associated with practice; the specific object in view being to ensure a "scientific" rather than a "professional" cast of thought. Each man to his trade. In the past, the progress of research has suffered much from the methods of the Jacks of all Sciences, whose work too often was not sufficiently fundamental to stand the test of time.

Agricultural chemistry is itself rapidly undergoing fission into specialised sections connected dominantly with some one or other branch of agriculture.

In regard to the science of Physiology the points of contact with chemistry, more particularly with physical chemistry, are so numerous that one can hardly venture to begin upon them. All the methods for the study of vital processes are either physical or chemical at bottom, and indeed Huxley defined the position of Physiological Science as "midway between the physico-chemical and the social sciences." Physiology itself divides naturally into two sections, "general" and "comparative." The latter is largely a descriptive science, dealing with the mechanism of living structures, and merges into morphology and anatomy. General Physiology is much more fundamental, and deals with the way the mechanism works; deals more with the underlying interpretation of physiological phenomena, than with the simple description of functions. It is therefore the side upon which Chemistry most naturally joins forces. The borderline science of "Physiological Chemistry" has been singularly fruitful in recent years, and though its independent status is but recently acquired it now carries its own department, and usually its own professorship, in progressive universities. The somewhat wider term "Biochemistry" is usually used as synonymous with "Physiological Chemistry," but as the term signifies the "chemistry of life" its scope is so wide that still further fission is under way. On the botanical side it is rapidly developing the independent off-shoot "Phytochemistry." The various branches of agricultural chemistry, except in so far as they are purely analytical, also come under the biochemical group, and require a working knowledge of one or more of the biological sciences.

The science of Bacteriology, founded on a scientific basis by the famous French chemist Pasteur, is an off-shoot of chemistry which has long since attained its independent status, and although still little more than a fusion product of Chemistry and Botany in so far as pure Bacteriology, Agricultural Bacteriology, and Industrial Bacteriology, are concerned, its importance in human medicine has tended to associate it in the popular mind with Pathology. The general medical bacteriologist, however, is rarely a chemist, and since the days of Pasteur pure Bacteriology has suffered much from too close an association with Pathology. The modern Universities are now separating the two subjects.

A new borderline between Chemistry and Pathology is fast attaining importance, and progressive institutions, such as St. Thomas's Hospital in London, have independent lecturers on Chemical Pathology.

Where the chemist takes to Medicine we get fresh borderlines developed; as in the case of Ehrlich, who was chemist first and medico afterwards, and did so much for the development of immuno-chemistry. It is interesting to note that the famous "side-chain" theory of immunity is a direct analogy from organic chemistry, and that although it has well served its day the future development of immuno-chemistry promises to turn on the chemistry of colloids.

It may be added that Professor Ehrlich was also the pioneer in the new line of "chemotherapy," a borderline between chemistry and therapeutics. Since this is of popular as well as of purely scientific interest, an illustration may be taken of the ultimate fashion in which the discovery of new remedies in medicine depends upon combination of chemcial and physiological knowledge. "Salvarsan," "606," the notoriety of which has spread to the populace on account of its use in curing the social scourge of syphilis, offers one of the best examples. The problem before Ehrlich, when he embarked upon his researches, was to obtain a poison which, when injected into the blood-stream, would destroy disease-producing organisms without affecting the tissues of the body, *i.e.*, to prepare a *selective* drug. At first sight such a problem appears to be too complicated for solution, but the analogy of the dyeing vat came to the rescue. It was well known that certain dyes which would give a "fast colour" with silk would not do so with cotton, and the same principle applied to the selective staining of bacteria and tissues, was already giving fruitful results in biology. It was also empirically known that compounds of Mercury were useful in the treatment of syphilis, although the causal organism (*Treponema pallidum*) of the disease had not yet been discovered. Unfortunately, however, Mercury compounds could not be used in adequate amount owing to their poisonous action on the patient, and the problem became one of getting the mercury into a dye-like compound, which would be selectively fixed by the organism without killing the patient; in other words, to "cover" the mercury with chemical groupings for which the causal organisms had a special affinity, but for which the tissues of the body had not. It was soon found, however, that dye-mercury compounds were unstable in the body, and that the mercury was too easily set free again in a form poisonous for the subject. The next problem was to find a substitute for mercury which could be effectively "covered" in such a way as to combine a harmless grouping for which the disease organism had some special affinity, with a toxic group which would kill it. The element arsenic seemed promising, and Ehrlich, in colloboration with others, finally succeeded in preparing the compound "Salvarsan," the chemical name for which is 3:3′-diamino-4:4′—dihydroxyarsenobenzene-dihydrochloride. Only the expert chemist can realise the enormous amount of labour and ingenuity expended in the research which culminated so brilliantly; involving, as it did, the devising of methods for synthesising unknown organic derivatives of arsenic, and the elaborate testing of the new compounds. But some idea of the labour involved is indicated by its laboratory nick-name "606"—success came only after the six hundred and sixth compound was prepared. Further researches, along similar lines, for specifics against bacteria, spirochætes, and trypanosomes, are now in progress all over the world, and it seems probable that a new era has been heralded in the long combat against disease. But the practitioner must not expect immediate results. The number of compounds of the class under consideration is rapidly going up into the thousands, but the chase is a long one. One of the most recent derivatives, "Margol" or "102," is a complex organic compound of arsenic, antimony, and silver, and is claimed to be superior to Salvarsan for the treatment of Syphilis. As the connection between chemical constitution and physiological action becomes gradually worked out by the pure sciences, fresh lines of application to medicine will suggest themselves.

It would take us too far off the main track of the ramificatoins of chemistry to go into other subdivisions of the borderline science of biochemistry.

On the industrial side, it may be mentioned that subjects such as Brewing are dominantly biochemical, and that the director of the school of Brewing in the University of Birmingham is a biochemist of the first order, who has turned out work of fundamental interest to the science. In Birmingham University a diploma in Brewing is granted to students taking a three-year course, while a degree course in the Biochemistry of Fermentation is provided for students who intend to devote themselves to the upper reaches of their subject. It may be added that the whole progress of brewing, from the time of Pasteur onwards, has been a chemist's progress.

In regard to the industrial ramifications of chemistry, space forbids further mention. Suffice it that there is no industry into which the chemist has not penetrated, and many industries depend for their whole existence upon some basic chemical discovery or continued chemical control. Thus the development of the whole mining industry of the Witwatersrand, and the very coming into existence of the city of Johannesburg, was conditioned by a laboratory observation made originally by a pure chemist, and developed by a mineralogical chemist—who, it may be added, did not get enough out of his patent to enable him to abandon his practice. The cyanide process for the extraction of gold from low-grade ores and tailings makes just that difference between profitable and unprofitable production of gold in South Africa, and without it the industries of the Witwatersrand would never have reached their present development.

In the application of his science to the industries the chemist has three lines of activity. He may be asked to control the technical aspects of the industry entirely, owing to the fact that they are so dominantly chemical as to make "fool-proof" methods impossible of application. Or he may be asked to step in and subject an existing empirical process to scientific study, and devise methods whereby it may be improved. Or he may be asked to discover a totally new method of carrying out some desired operation, the need for which is obvious, and upon which an industry is to be built up. Of this last line we may take as examples the problem of the commercial utilisation of atmospheric nitrogen, and of the preparation of synthetic rubber. The atmospheric nitrogen problem was still in the hands of the theorists 18 years ago. At the present day it has been solved in several different ways, and millions of pounds worth of nitrate and ammonium compounds are produced per annum. Had it not been for the processes discovered shortly before the war Germany would have been beaten before 1915 was out, since she was completely cut off from the natural sources of nitrogen previously used for explosives. In this connection the words of Lord Moulton at the last annual dinner of the Chemical Society in London, are of interest:—

"Few people, I think, realised the extent to which this war was based on chemists and chemical progress. There is not the slightest doubt that the dogs of war were held in leash until the completion of those great installations which produced ammonia by the Haber process. Germany was wise enough to realise that she must not be cut off from her nitrates unless she could produce at home ammonia in the vast quantities required for the nitric acid for explosives, and she waited until the magnificent installations were completed by which she could attain this end. That was not all. The Germans knew that this war would be a war on an enormous scale, utterly deceived as they were as to the length of time during which it would last, and they looked to the large chemical installations for the manufacture of dyes and other chemical products to be the source of the munitions necessary to carry on the war."

But the fact that the solution of the problem of fixation of atmospheric nitrogen made war possible for the Central Powers must not be allowed undue prominence. The problem was not solved with that end in view. Rather let us hope that chemistry will make war altogether impossible before another war-broth has time to brew, and dwell upon the other side of the picture of nitrogen-fixation; turn our eyes rather to spectacles like that of Saaheim in Norway, which was transformed from a little village of 50 poverty-stricken farmers in 1903 into a prosperous town of six thousand inhabitants in 1913. Britain alone imported one and a half million pounds worth of Chili nitrate per annum in times of peace, and used still more nitrogen in other forms—herself producing nearly half a million tons of ammonium sulphate per annum from coal.

The peaceful operation of fertilising the soil is one of the largest outlets for combined nitrogen, and the significance for the world of the conversion of "air and water-power" into nitrate is incalculable.

The second illustration we have selected of the importance of "Industrial Chemistry," concerns the future. The labours of the pure organic chemists on the synthesis of rubber are not yet over, as the applications for patents show, but synthetic rubber has been produced by several methods, such as the action of Sodium on the hydrocarbons Isoprene and Butadiene. The starting point for the preparation of Butadiene is Butyl Alcohol which in turn is produced from Starch by the action of a microorganism—another leaf which can be added to the laurel-wreath of Biochemistry. One of the other products of the same fermentation of starch is Acetone, a solvent much used in the making of explosives, and for which Britain was in temporary desperation shortly after the outbreak of war. To the glory of our science that desperation was only temporary.

But the peaceful production of rubber from "potatoes and salt" is not yet a commercial proposition. The rubber is superior in some respects to natural rubber, but the technical difficulties in the way of the synthetic process are still too great to allow of commercial success, so that the shareholders in rubber plantations need have no immediate fear of bankruptcy. Fortunately for them, scientific research takes time, and the cheap synthetic rubber which is destined to pave our city streets, is likely to come on to the market so slowly as to give ample time for the plantation areas to turn to providing nutriment for those tramping over the synthetic enemy.

So much, then, for the ramifications of chemistry, that most basic of sciences (*pace* sister Physics and brother Mathematics), pursued for her own sake by the pundit, cultivated for ulterior motives by the worldly-minded (*pace* all sensible people): life-time study for her devotees, first-year nuisance for the practising professions (*pace* Mr. Doctorman, member not of the "oldest profession in the world," but of the one with the strongest trade-union).

These ramifications of the science have only been touched upon, but should suffice to show the fashion in which the pure science is throwing out tentacles to other sciences; itself suffering fission and then conjugation; narrowing by specialisation and widening by encroachment. On the one side the science has an Octopus aspect; on the other it suggests the primordial protoplasm of the evolutionary tree. It must have been the Octopus aspect which appalled Mr. Warington Smythe when, in a witty comment upon Dr. Juritz's presidential address last year, he murmured, "What a miserable worm every one of us who is not a chemist must feel!" But it is the protoplasmic activity of the science which concerns the world.

It has been shown that specialisation in Chemistry is inevitable; that there is no such thing as the "compleat chemist" as there was a century ago, when all that was known could come within the compass of a single brain, and the principles involved were easily grasped.

Remains then the question of how to educate the specialists. In the past this question has been allowed to settle itself, and the borderlines of sciences were left to individual enterprise. The exponent of one science was left to overlap into another as curiosity, fate, or gambling instinct, led.

The pure chemist passed into applied chemistry by following a point of contact with another science, and then becoming a master of the new field. One of the foremost agricultural chemists of the present day was a pure chemist, who became interested in the borderline by the cultivation of roses. Other agricultural chemists, men who have built up the science, are such by decree of fate; happened to get jobs which brought them into contact with agriculture, and compelled the acquiring of the requisite knowledge of that subject.

In the Industries the pure chemist of the older generation suffered metamorphosis into the industrial chemist by the necessity for grasping the essentials of an industry which he was called upon to help. Very often downright cupidity was the motive power, and cases are not uncommon of a pure chemist patenting an idea and then turning manufacturer in order to exploit it. In transition he had frequently to develop into a very presentable engineer. Sometimes the hybrid resulted from the manufacturer turning chemist, but this was less frequent owing to the basic nature of chemistry itself, and was generally only successful when the chemistry demanded was of a comparatively simple order. One can, for instance, hardly imagine a manufacturer of rubber goods turning chemist and discovering synthetic rubber, whereas it requires no stretch of imagination at all to visualise the chemist switching from the small scale to the large scale and turning manufacturer. Our modern millionaire chemists, like Sir George Beilby, are examples.

The chemists who crossed the borderline, not into industry but into other pure sciences, were men actuated chiefly by the simple love of research, and who saw there profitable fields for fresh discovery and "scientific reputation." A borderline science "in process of becoming" is always a fruitful field for the enquiring spirit, tired of the beaten track, and relatively careless of gain. And of such is the Kingdom of Science. Fortunately for the world's progress, man's rise from the beasts has bred a big sprinkling, who care more for high thinking than high living, and who are satisfied with a competency and an intellectual life. For the benefit of our national administrators let us hasten to emphasise that there is no fundamental incompatibility between high thinking and high living; that the world's masterpieces of art were painted on pork-chops, and that even the purest of scientific palates can appreciate a little sherry in the trifle!

In the border-lines between two pure sciences it frequently happened that men came over into the new territory from both sides. Thus in that branch of Biochemistry which lies at the junction of Chemistry and Physiology, and is still young, chemists have gone over into Physiology, and physiologists come over into Chemistry; becoming then "Physiological Chemists" or "Chemical Physiologists," according to their starting-points or their bias. Although the investigating temperament is not one which depends upon its past academic education for its knowledge throughout life, but is student all its days, it is still true that the early bias tends to reflect itself in all the subsequent work of the investigator, and early training is a matter of no small importance.

The best work is frequently accomplished by collaboration between different investigators crossing into the same territory from different sciences. Each then brings the specialised technique, ideas, and cast of mind, characteristic of his own science. Sound collaboration between equals is the best way of developing new sciences or of applying old sciences to new problems. The very prejudices of each science can then be turned to account— flint striking on flint generating the sparks of truth.

So long, then, as any science is in its infancy, it can only have one mode of development—fission from existing sciences. Orthodox training is not yet provided, and the science is dependent wholly upon private enterprise; upon "foreign adventurers," of whom any country may be justly proud. As soon, however, as development is advanced, and the demand for students of the new science is created, it is possible to arrange specifically for their training, and to offer one or more definite professional courses for the coming generation. This is what has happened in the case of the best-known "orthodox" professions and professional applied sciences. Time was when the apothecary plied the bleeding-cup and saw, and was physician and surgeon of his day. That day is long past, and once the medical profession established itself, and arranged its professional training, it soon succeeded, in virtue of the supreme importance attached by even the highest in the land to their own skins, in forming a closed ring and keeping out the layman. Time also was when the veterinarian was the local farrier. That time, too, is gone, although it is only within recent years that the calling has won into the ranks of the clearly defined professions and claimed its knighthoods for services rendered to the community. The passing of "general practice" and the increasing significance of the veterinarian in matters of "State Hygiene," is bringing the profession daily into greater prominence. It has a clearly defined four years' college training for diploma purposes, any specialised training which the more scientifically-minded are disposed to undertake being left to the science faculties of other institutions, or to post graduate study.

So also with dentistry, a profession which is fast passing out of the hands of the merely muscular into the hands of qualified and scientifically trained men.

So also with other orthodox callings. As soon as the demand for a stereotyped general training becomes great enough, it is met by organised teaching institutions. Industrial Chemistry and Chemical Engineering now belong to that group. The Charlottenburg Institute in Berlin offers a seven years' course (D.Ing.) in Industrial Chemistry. Most of the British technical Institutions offer a four years' course, leaving the student to develop his profession further in actual contact with the particular industry into which he passes, or to undertake specialisation by post-graduate study.

The practising profession of "Analytical Chemistry," and the various requirements of the "consulting chemist," are likewise met by orthodox curricula. In the nature of the profession, however, the analytical chemist tends to rapid specialisation, and this is recognised by the Institute of Chemistry, which, although it demands a sound knowledge of general chemistry in its intermediate examination, allows of specialisation in its final, and demands special knowledge of one of seven groups: (*a*) Mineral Chemistry, (*b*) Metallurgical Chemistry, (*c*) Physical Chemistry, (*d*) Organic Chemistry, (*e*) Chemistry and Microscopy of Food and Drugs, Fertilisers and Feeding Stuffs, Soils, Water, etc.; including the chemical-legal aspects of the group, (*f*) Biological Chemistry and Bacteriology, (*g*) Chemical Technology.

Analytical Chemistry can, of course, be treated as a separate science, but as a practising profession it is more orthodox, and serves some definite social function or some defined State purpose, like the calling of the unspecialised medical practitioner. Unlike medicine, unfortunately, its major activities are not a matter of human life and death, and it is, therefore, much more difficult to exclude the "quack." The sphere of the analyst is too wide to allow of State specification of his functions. The State cannot interfere with a "fellow who wants to analyse things," or with one who fancies himself as a consulting chemist. All it can do is to take care that he is not allowed to do State work without recognised qualifications. This it does do—Government, County, and Municipal Analysts, must all be men of recognised status. The same course of procedure is adopted with members of other practising professions, the malpractice of which only incidentally endangers human life: the electrical engineer, the naval architect, the practitioner of any other group of applied sciences. Since there is no need for the law of the land to guard such professions against a charge of homicide, the community is left to look after its own interests and protect itself against quackery by the exercise of its own common sense. All the law can do is to specify that no man shall style himself that which he is not, but in the nature of things it is not easy to interfere with the liberty of the subject in calling himself names.

The problem has to be faced, however, and if the public is to be protected against the quack, some process of legislative interference with this liberty will have to be devised. The question is partly a matter for legislative action and partly a matter for organisation along trade union lines.

The established professions are thus fairly well looked after in regard to the training available for youthful aspirants to their service. A regulation academic course is provided, and the matriculated student knows exactly what he has to do—do a humdrum rat-rat through the curriculum, taking the ordinary precautions against getting "ploughed." Provided the career offered is sufficiently respectable, and sufficiently remunerative to outrival the boyish fancy for brick-laying or engine-driving, there will be no dearth of trained men; and if a sufficient number of professional plums are within reach, there will be the necessary incentive to ability and energy. The rising tide of students at the Universities, backed by the free education of the secondary schools, will see to it that anything decent and anything orthodox does not lack recruits.

There is, of course, scope for improvement in all orthodox curricula—vast scope. But the need for improvement and the direction it should take, are usually easy to recognise. Otherwise is it with the more specialised worker who hopes to devote his life to research; more markedly otherwise when his research takes him to the border-lines of his science; and yet more markedly otherwise when his science is the fundamental one of Chemistry

If he is to be a specialist his training in his main subject must be fairly prolonged. The major portion of the time otherwise spent in training for an orthodox professional career must be spent in a more intense concentration on the subject in which he afterwards hopes to do research, and more particularly in the time-consuming task of acquiring "practical technique." Unless his training is to be unduly prolonged his "cognate subjects" must be well chosen, so as to bear upon the prospective border-line, and he must select some unorthodox curriculum for himself. Since this is a sporting procedure, and demands a stronger individuality, or at least a more impelling individual taste, the number of men consciously taking to border-line sciences will remain few, unless some definite career is offered by which consciousness is aroused. As a rule, this incentive is absent, since border-line specialisation precedes its own public recognition, and remunerative occupation therein is "chancey." As soon, of course, as the border-line is roughly mapped out by inquisitive spirits from the pure sciences, the economic possibilities of the new territory become apparent. But the territory remains imperfectly exploited until it is in the position to offer a career to the "honest hodmen of science," whose labour is so necessary to develop it.

The first exploration may demand genius of the highest order; such genius as only appears at intervals in the history of science. But the developing of the new scientific territory demands a host of ordinary, presentable, well-trained brains and capable hands.

The problem of the development of the border-lines of a science, is therefore three-fold.

First and foremost, the purely scientific worker with no utilitarian end in view must be encouraged. Since his end is not utilitarian, but his nutritional needs none the less pressing for that, he must either side-track himself in seeking nutriment in ways alien to his work, in subsidiary uncongenial tasks as the price of his researches: or he must depend upon private or State endowment. The search for truth for its own sake has been hampered through all the ages by the unfortunate circumstance that the most earnest seeker after truth has got a stomach. Private endowment of pure research has done much for progress, especially in America, where it is now fashionable for industrial millionaires to return part of their spoils to strengthen the ladder by which they climbed; as witness Rockefeller. But any nation which relies upon private enterprise for encouraging non-utilitarian work is destined to disaster; is, at any rate, an ass. There must be national endowment of pure research, of the pursuit of knowledge for its own sake, and copious endowment at that. Pure research is the basis upon which the superstructure of economic progress is built.

Secondly, but not less important, there must be provision for the band of workers who commence to carry the data of pure science into fields where it may find its economic application;

who *commence* to apply the science, and carry out research in the zone between abstract truth and downright utility. These are the pioneers of the profession to follow. This phase of the development, also, can not safely be left to look after itself, since in its early stages it must suffer from many failures, and can offer no assurance of a livelihood. It will not attract those "in search of a career," and will therefore suffer neglect. It is a phase of development which is highly specialised, but which has not yet obtained full recognition. It is still "pure science" —pure science doing its best to get itself applied. State endowment is imperative, either direct in the form of grants to Universities for "research fellowships" and "research professorships," or indirect by encouragement of such work in State institutions of a scientific character. This latter method is important, and should not be overlooked, since such institutions are usually well off for apparatus and material for research, and it costs but little to encourage "human quality."

Thirdly comes the every-day application of the results and methods to utilitarian ends. The new science finds its feet, demonstrates its utility to the "layest" of minds, and is no longer so dependent upon endowment. It is self-supporting, obviously adds to the wealth or well-being of the world, and provides careers for whomsoever cares to take it up. The tools are there, the lines of application mapped out, and the journeyman can do the rest. The applied science passes over into a trade. If Britain had spent a trifle in encouraging pure scientific research half a century ago, she would have saved herself the ignominy of having to spoon-feed her industries to-day.

It must never be lost sight of that the purely scientific investigator lays the foundation-stones for the superstructure. Science cannot be applied until there is science to apply, and the genesis of science is always pure in the sense that each link in the chain of development must be forged independently of any purpose to which the whole chain may finally be put. As Huxley put it "What people call Applied Science is nothing but the application of Pure Science to particular classes of problems."

But Applied Science is something anyone can understand, since it touches every-day experience, and there is a danger that applied science will be endowed to the detriment of pure science The aims of the pure researcher are not so easy to grasp, for the very training in science tends to exalt the idea of knowledge for its own sake, and shed a halo round an hypothesis. It is, perhaps, not easy for the utilitarian to realise the glow of satisfaction which suffuses the mind of the investigator when he feels that his work has opened up a fresh line of thought, or added some cardinal piece of truth to the body of human knowledge, or pricked some current fallacy. The glow is not so very much more intense when the work obviously has an immediate practical application—at any rate, he can glow quite satisfactorily without that! None the less, it is very much to the interest of even the most pure-minded investigator if he keeps an open eye upon any immediate practical applications. It so happens, however, that the greatest discoveries are made with no eye to their immediate usefulness. When Faraday called his wife into his laboratory to show her the first toy progenitor of the modern electro motor, his enthusiasm was not disturbed by any considerations concerning the practical value of his discovery—he never made a cent out of it, anyway, though the brains which developed his visions were much inferior to his own. The man of affairs is apt to take the production of some valuable new product, by the application of well-worn principles, as a "triumph of science," but it is not for such triumphs that the scientific societies bestow their honours. The worker who is honoured by his colleagues is the one who widens the horizon of truth and knowledge.

It is sincerely to be hoped that the administrators and statesmen who guide our national destinies, now that they have wakened to the need for scientific research, will not fall into the trap of encouraging *only* the "applied sciences" whose immediate utility they can grasp, but will be far-sighted enough *also* to encourage science in the abstract, pure and unalloyed. To them may be commended a study of the history of science. It can never be predicted how soon an abstract laboratory observation will develop enormous economic importance. One of the most striking instances of this is provided by the Hertzian electric waves, which were referred to in the first edition of Karl Pearson's "Grammar of Science," as of no practical application, but which were used for wireless telegraphy by Marconi before the second edition had appeared. But before Hertz came Crookes, and before him Hittorf, Geisler, Maxwell, De la Rue, right back to Faraday, all studying the electric discharge for its own sake; each advancing his science step by step along its logical line of development with no inkling of the future economic significance of his labour. That is the history of science. As Pope said of Leblanc and Faraday: "It is impossible to calculate the capitalised value of the alkali industry founded by Leblanc, who committed suicide owing to poverty, or of the chemical industries based on the work of Michael Faraday, who ended his days in comparative comfort on a Civil List pension."

The administrators who control the money-bags must not ask to see their money's worth before they spend the money. Scientific discovery of any vital kind can not be made to order, although to a certain extent the results of scientific research can easily be applied to order. But science in the abstract must come first and foremost. Scientific Education and Applied Science must run parallel. For the nations which spend most freely in scientific education and research, can be prophesied the greatest economic prosperity.