Title: The Progress of the Century

Author: Various

Release Date: September 14, 2017 [EBook #55546]

Language: English

Character set encoding: UTF-8

Produced by Chris Curnow, Charlie Howard, and the Online
Distributed Proofreading Team at http://www.pgdp.net (This
file was produced from images generously made available
by The Internet Archive)

THE PROGRESS

OF THE

CENTURY

BY ALFRED RUSSEL WALLACE; PROF. WILLIAM RAMSAY; PROF. WILLIAM MATTHEW FLINDERS-PETRIE; SIR JOSEPH NORMAN LOCKYER; EDWARD CAIRD; WILLIAM OSLER; W. W. KEEN; PROF. ELIHU THOMSON; PRESIDENT THOMAS CORWIN MENDENHALL; SIR CHARLES WENTWORTH DILKE; CAPTAIN ALFRED T. MAHAN; ANDREW LANG; THOMAS C. CLARKE; CARDINAL JAMES GIBBONS; REV. ALEXANDER V. G. ALLEN; PROF. RICHARD J. H. GOTTHEIL; PROF. GOLDWIN SMITH

NEW YORK AND LONDON
HARPER & BROTHERS PUBLISHERS
1901

iii

CONTENTS

PAGE

EVOLUTION. By Alfred Russel Wallace, LL.D., D.C.L., F.R.S 3

CHEMISTRY. By Prof. William Ramsay, Ph.D., F.R.S., F.C.S., Officer of the Legion of Honor 33

ARCHÆOLOGY. By Prof. William Matthew Flinders-Petrie, D.C.L., LL.D., Edwards Professor of Egyptology, University College, London 73

ASTRONOMY. By Sir Joseph Norman Lockyer, C.B., F.R.S., Director of Solar Physics Observatory, South Kensington 105

PHILOSOPHY. By Edward Caird, LL.D., D.C.L., Professor of Moral Philosophy, Glasgow 145

MEDICINE. By William Osler, LL.D., Professor of Medicine and Physician to Hospital, Johns Hopkins Medical School 173

SURGERY. By W. W. Keen, M.D., LL.D., F.R.C.S. (Hon.), Professor of the Principles of Surgery and of Clinical Surgery, Jefferson Medical College, Philadelphia 217

ELECTRICITY. By Prof. Elihu Thomson, A.M., Ph.D., Chevalier and Officer of the Legion of Honor 265

PHYSICS. By President Thomas Corwin Mendenhall, Ph.D., D.Sc., LL.D., Member National Academy of Science 303

WAR. By the Right Hon. Sir Charles Wentworth Dilke, LL.M. 333 iv

NAVAL SHIPS. By Captain Alfred T. Mahan, late U.S.N., D.C.L., LL.D. 355

LITERATURE. By Andrew Lang, Hon. Fellow Merton College, Oxford 389

ENGINEERING. By Thomas C. Clarke. Past President of the American Society of Civil Engineers 421

RELIGION:

Catholicism. By Cardinal James Gibbons 455

Protestantism. By Rev. Alexander V. G. Allen, Professor of Church History in the Episcopal Theological School at Cambridge, Mass. 477

The Jews and Judaism. By Professor Richard J. H. Gottheil 498

Free-Thought. By Professor Goldwin Smith 539

EVOLUTION

Among the great and fertile scientific conceptions which have either originated or become firmly established during the nineteenth century, the theory of evolution, if not the greatest of them all, will certainly take its place in the front rank. As a partial explanation (for no complete explanation is possible to finite intelligence) of the phenomena of nature, it illuminates every department of science, from the study of the most remote cosmic phenomena accessible to us to that of the minutest organisms revealed by the most powerful microscopes; while upon the great problem of the mode of origin of the various forms of life—long considered insoluble—it throws so clear a light that to many biologists it seems to afford as complete a solution, in principle, as we can expect to reach.

THE NATURE AND LIMITS OF EVOLUTION

So many of the objections which are still made to the theory of evolution, and especially to that branch of it which deals with living organisms, rest upon a misconception of what it professes to explain, and even of what any theory can possibly explain, that a few words on its nature and limits seem to be necessary.

Evolution, as a general principle, implies that all things in the universe, as we see them, have arisen from other things which preceded them by a process of modification, under the action of those all-pervading but mysterious agencies known to us as "natural forces," or, more generally, "the laws of [4] nature." More particularly the term evolution implies that the process is an "unrolling," or "unfolding," derived probably from the way in which leaves and flowers are usually rolled up or crumpled up in the bud and grow into their perfect form by unrolling or unfolding. Insects in the pupa and vertebrates in the embryo exhibit a somewhat similar condition of folding, and the word is therefore very applicable to an extensive range of phenomena; but it must not be taken as universally applicable, since in the material world there are other modes of orderly change under natural laws to which the terms development or evolution are equally applicable. The "continuity" of physical phenomena, as illustrated by the late Sir William Grove in 1866, has the same general meaning, but evolution implies more than mere continuity or succession—something like growth or definite change from form to form under the action of unchangeable laws.

The point to be especially noted here is, that evolution, even if it is essentially a true and complete theory of the universe, can only explain the existing conditions of nature by showing that it has been derived from some pre-existing condition through the action of known forces and laws. It may also show the high probability of a similar derivation from a still earlier condition; but the further back we go the more uncertain must be our conclusions, while we can never make any real approach to the absolute beginnings of things. Herbert Spencer, and many other thinkers before him, have shown that if we try to realize the absolute nature of the simplest phenomena, we are inevitably landed either in a contradiction or in some unthinkable proposition. Thus, suppose we ask, Is matter infinitely divisible, or is it not? If we say it is, we cannot think it out, since all infinity, however it may be stated in words, is really unthinkable.

If we say there is a limit—the ultimate atom—then, as all size is comparative, we can imagine a [5] being to whom this atom seems as large as an apple or even a house does to us; and we then find it quite unthinkable that this mass of matter should be in its nature absolutely indivisible even by an infinite force. It follows that all explanations of phenomena can only be partial explanations. They can inform us of the last change or the last series of changes which brought about the actual conditions now existing, and they can often enable us to predict future changes to a limited extent; but both the infinite past and the remote future are alike beyond our powers. Yet the explanations that the theory of evolution gives us are none the less real and none the less important, especially when we compare its teachings with the wild guesses or the total ignorance of the thinkers of earlier ages.

THE RISE AND PROGRESS OF THE IDEA OF EVOLUTION

If we trace, however briefly, the gradual development of knowledge and speculation on this subject, we shall perhaps appreciate more fully the advance we have really made during the present century.

The first speculations on the nature and source of the phenomena of the universe, of which we have any knowledge, are those of the early Greek philosophers, such as Thales, Anaximander, Anaxagoras, and Empedocles; but as the more important of their teachings are embodied, with some approach to system and with much acuteness of reasoning, in the great poem of the Latin author Lucretius, "On the Nature of Things," it will be sufficient to give a sketch of his main conclusions, making use of the excellent prose translation by Mr. H. A. J. Munro, of Trinity College, Cambridge.

Lucretius had a very clear idea of the indestructibility of matter. He argues that things cannot have 6
come out of nothing, and he says: "A thing never returns to nothing, but all things, after disruption, go back into the first bodies of matter." He then argues that, as the actual processes of growth, decay, and other natural changes are imperceptible to us, therefore "Nature works by unseen bodies." He justly claims great importance for the demonstration of the fact that in all matter whatever, however solid and hard it may be, there are vacancies, or, as he expresses it, "Mixed up in all things there is void or empty space." He thus anticipated the modern doctrine that the molecules of matter do not come into actual contact. He then defines atoms thus: "First bodies are solid and without void"; and as nothing can be produced from nothing, he concludes that these first bodies (atoms or molecules) must be everlasting, and that they supply matter for the reproduction of all things.

He then goes on to prove that these "first beginnings are of solid singleness, not formed of parts, but strong in everlasting singleness." He further proves that these "first beginnings" (atoms) cannot be infinitely small, and also that the universe cannot be limited—that it is infinite. He thus anticipated the main ideas as to atoms and the universe which have been held by most materialistic thinkers down to our own times.

Lucretius was an absolute materialist, for though he did not deny the existence of the gods he refused them any share in the construction of the universe, which, he again and again urges, arose by chance, after infinite time, by the random motions and collisions and entanglements of the infinity of atoms. He assumes some forces analogous to gravitation and the molecular motions of gases in the following passage: "For the first beginnings of things move first of themselves; next these bodies 7
which form a small aggregate and come nearest, so to say, to the powers of the first beginnings are impelled and set in movement by the unseen strokes of these first bodies, and they next in turn stir up other bodies which are a little larger."

He also anticipated Galileo as to the equal speed of all falling bodies when not checked by the air in the following precise statement: "For whenever bodies fall through water and thin air they must quicken their descents in proportion to their weights, because the body of water and subtle nature of air cannot retard everything to an equal degree; on the other hand, empty void cannot offer resistance to anything in any direction at any time, but must continually give way; and for this reason all things must be moved and borne along with equal velocity, though of unequal weights, through the unresisting void."

This is a wonderfully accurate general statement of the equal rate of motion of all kinds of matter under the same forces; and when we consider that there is no indication of any experimental basis for this conclusion, and that nothing equivalent to our sciences of physics or chemistry existed, we are amazed at the general correctness of many of his views, derived solely by a process of reasoning from the most obvious phenomena of nature. He argues that, given infinite matter and space and inherent motion, “things must go on and be completed,” and his general conclusion is thus expressed: “If you will apprehend and keep in mind these things, nature, free at once and rid of her haughty lords, is seen to do all things spontaneously of herself without the meddling of the gods.”

It is when he attempts to deal with the origin of living organisms that the absence of all knowledge of chemistry, physiology, and histology renders his task impossible and leads him into what seem to us the wildest absurdities. He has an elaborate but very unconvincing argument that sensation can arise 8
out of atoms which have no sensation; and, taking the appearance of worms, etc., in the earth and in putrid matter as a proof that they are still actually produced *de novo* in it, he argues that at some remote epoch the now worn-out earth was more fertile, and produced in like manner all kinds of animals. The first human infants he supposes to have been formed at some very remote time in the manner following: “For much heat and moisture would then abound in the fields; and therefore wherever a suitable spot offered wombs would grow, attached to the earth by roots; and when the warmth of the infants, flying the wet and craving the air, had opened these in the fulness of time, nature would turn to that spot the pores of the earth and constrain it to yield from its opened veins a liquid most like to milk. To the children the earth would furnish food, the heat raiment, the grass a bed rich in abundance of soft down.... Wherefore, again and again I say, the earth, with good title, has gotten and keeps the name of mother, since she of herself gave birth to mankind, and at a time nearly fixed shed forth every beast that ranges wildly over the great mountains, and at the same time the fowls of the air with all their varied shapes.”

The fact that this mode of origin commended itself to one of the brightest intellects of the first century B. C., enlightened by the best thought of the Grecian philosophers, may enable us the better to appreciate the immense advance made by modern evolutionists.

THE FIRST REAL STEPS TOWARDS EVOLUTION

We have now a great blank of fifteen centuries—the dark ages of human progress—after which the era of observation and experiment began, and for the first time men really set themselves to study 9
nature, thus laying the foundation for all the great theoretical advances of our time. As leading to the next great step in theories of evolution, we must note the life-long observations by Tycho Brahe of the apparent motions of the planets; the grand discovery of Kepler that all these apparently erratic motions were due to their revolution round the sun in elliptic orbits, with a fixed relation between their distance from the sun and their periods of revolution; and Newton’s epoch-making theory of universal gravitation by which all these facts and many others since discovered were harmonized and explained.

But all this implied no law of development, and it was long thought that the solar system was fixed and unchangeable—that some altogether unknown or miraculous agency must have set it going, and that it had in itself no principle of change or decay, but might continue as it now is to all eternity. It was at the very end of the eighteenth century that Laplace announced his “Nebular Hypothesis,” the first attempt ever made to explain the origin of the solar system under the influence of the known laws of motion, gravitation, and heat, acting upon an altogether different antecedent condition of things—a true process of evolution.

Laplace supposed that the whole matter of the solar system was once in a condition of vapor, and that it formed an enormous nebulous mass many times larger than the then known dimensions of the planetary sphere. He showed how, under the influence of gravitation, this nebula would condense, and that such irregularities of motion and density as would be sure to exist would lead to rotation of the mass. Under the law of gravitation this would lead to outer rings being left behind by the contraction of the central mass, which rings would at a later period become drawn together at some point of initial greater density and thus form planets. The whole process is admitted to be mathematically 10
demonstrable, given the initial conditions; but recent extensions of our knowledge of the interplanetary and interstellar spaces have shown that the supposed void is really full of invisible solid matter,

ranging from the bulk of the smaller planets down to the finest dust, and it is very difficult to imagine any possible causes which would keep all the solid matter of the system in a state of vapor, when subject, on the confines of the mass, to the cold of interstellar space. The antecedent condition of our system is now thought to have been either wholly or partially meteoritic, but in either case we have a genuine theory of its evolution which has now been so extended as to include the appearance of comets and meteors, of nebulæ, and star clusters, of temporary, periodic, and colored stars, and many other phenomena of the stellar universe. It is no objection to these grand theories to urge that they do not explain the origin of the matter of the universe, either what it is or how it came to be where we now find it. We can only take one step at a time, and even if in these greater problems any further advance should be as yet denied us, it is still a great thing to have been able to take even one secure step into the vast and mysterious depths of the interstellar spaces.

EVOLUTION OF THE EARTH'S CRUST

Although Pythagoras (500 B. C.) believed that sea and land must often have changed places, and a few other observers at different epochs came to the same conclusion, yet, till quite recent times, the earth was generally supposed to have been always very much as it is now; people spoke of "the eternal hills"; and the great mountain ranges, the mighty ravines and precipices, as well as the deep seas and oceans, were believed to be the direct work of the Creator.

It was only in the latter half of the eighteenth century that a few observers began to see the [11] importance of studying the nature of the earth's crust, so far as it could be reached in ravines, quarries, and mines; and one of the most earnest of these students, Dr. Hutton, of Edinburgh, after more than thirty years of travel and study, published his great work, *The Theory of the Earth*, which must be considered to be the starting-point of modern geology. He maintained that it was only by observing causes now in action that we can explain the phenomena presented by the stratified and igneous rocks; he showed that the former must have been laid down by water, and that the larger part of them, containing as they do marine shells and other fossils, must have been deposited on the sea-bottom. He showed how rain and rivers, frost and snow, wind and heat disintegrated the hardest rocks and would in time excavate the deepest valleys; while earthquakes, however small an elevation any one of them might produce, would in time raise the sea-bottom sufficiently high to form, when denuded, mountain ranges, plains, and valleys like those we now see everywhere upon the earth's surface. He also showed that the most ancient stratified rocks, those that lie at the very base of the series, presented every indication of having been formed in exactly the same way as the most recent ones. Hence he stated a conclusion which excited a storm of opposition, in these words: "In the economy of the world I can find no traces of a beginning, no prospect of an end." This was thought to imply a denial of creation, and was quite sufficient at that period to prevent the work of any man of science from being judged impartially.

But although Playfair and a few others upheld Hutton's views, they were too novel to receive much support by his contemporaries, and this was especially the case as regards the slow and continuous action of existing causes being sufficient to account for all the known phenomena [12] presented by the crust of the earth. Hence the belief in catastrophes and cataclysms—in great convulsions tearing mountains asunder, and vast floods sweeping over whole continents—continued to prevail, till finally banished by the genius and perseverance of one man, Sir Charles Lyell. His *Principles of Geology* was first published in 1830, and successive editions, revised and often greatly extended, continued to appear till the author's death, forty-five years later. As this work affords a fine example of the application of the principles of evolution to the later phases of the earth's history, and as it not only revolutionized scientific opinion in its own domain, but prepared the way for the acceptance of the still more novel and startling application of the same principles to the entire organic world, it will be necessary to show what opinions prevailed at the time it first appeared in order that we may understand how great was the change it effected.

In the earlier years of the nineteenth century the standard geological work, both in Great Britain and on the Continent, was Cuvier's *Essay on the Theory of the Earth*. In 1827 a fifth edition of the English translation appeared, and there was a German translation so late as 1830—sufficient proofs of its wide popularity. Yet this work abounds in statements which are positively ludicrous to any one conversant with modern geology. It never appeals to known causes, but again and again assumes forces to be at work for which no evidence is adduced and which are totally at variance with what we see in the world to-day. A few examples justifying these statements must be here given. Cuvier shows that he was acquainted with the theory of modern causes, but he altogether rejects it, saying that "the march of nature is changed, and none of the agents she now employs would have been sufficient for the production of her ancient works." He adduces "the primitive mountains" whose "sharp and [13] bristling ridges and peaks are indications of the violent manner in which they have been elevated." He allows that atmospheric agencies may form sea-cliffs, alluvial deposits, and taluses of loose matter at the foot of the precipices, but he adds: "These are but limited effects to which vegetation in general puts a stop, and which, besides, presuppose the existence of mountains, valleys, and plains—in short, all the inequalities of the globe—and which, therefore, cannot have given rise to those inequalities." He contrasts the calm and peaceful aspect of the surface of the earth with the appearances discovered when we examine its interior. Here, in the raised beds of shells, the fractured rocks, the inclined or even vertical stratification, he finds abundant proofs "that the surface of the globe has been broken up by revolutions and catastrophes."

He also refers to the numerous large blocks of the primitive rocks scattered over the surface of secondary formations, and separated by deep valleys or even by arms of the sea from the peaks or ridges from which they must have been derived, as further proofs of catastrophes; for, it is argued, they must have been either ejected by volcanic eruptions or carried by waters, which, in either case, "must have exceeded in violence anything we can imagine at the present day," and he therefore concludes that "it is in vain we search among the powers which now act upon the surface of the earth for causes sufficient to produce the revolutions and catastrophes, the traces of which are exhibited in its crust." He is quite confident that all these changes go on rapidly, periods of catastrophe alternating with periods of repose. The present surface of the earth he holds to be quite recent, and he maintains "that, if anything in geology be established, it is that the surface of our globe has undergone a great and sudden revolution, the date of which cannot be referred to a much earlier period than five or six [14] thousand years ago; that this revolution overwhelmed and caused to disappear the countries which were previously inhabited by man, and the species of animals now best known; that, on the other hand, it laid dry the bottom of the last sea, and formed of it the countries which are at the present day inhabited." And he further declares that "this event has been sudden, instantaneous, without any gradation; and what is so clearly demonstrated with respect to this last catastrophe is not less so with reference to those which preceded it."

The method followed by Lyell was the very reverse of that of Cuvier. Instead of assuming hastily that modern causes were totally inadequate, and appealing constantly to purely imaginary and often inconceivable catastrophes, Lyell investigated these causes with painstaking accuracy, applying the tests of survey and time measurement, so as in many cases to prove that, given moderately long periods of time—not a few thousands only, but hundreds of thousands of years—they were fully adequate to explain the phenomena. He also showed that the imaginary causes of Cuvier would not explain the facts, for that everywhere in the crust of the earth we found conclusive proofs of very slow continuous changes exactly analogous to what now occur, never of great convulsions, except quite locally, as we have them now. He showed that modern volcanoes had poured out vast masses of melted rock during a single eruption, covering areas as extensive as those which any ancient volcano could be proved to have ejected in an equally short period; that strata were now in process of formation comparable in extent and thickness with any ancient strata; that organic remains are being preserved in them just as in the older rocks; that the land is almost everywhere rising or sinking as of old; that valleys are being excavated and plateaus or mountains upheaved; that earthquake shocks are producing [15] faults beneath the surface; that vegetation is still preparing future coal beds; that limestones, clays, sandstones, metamorphic and igneous rocks are all still being formed; and that, given time, and the intermittent or continuous action of the causes we can now trace in operation, and all the varied features of the earth's surface, as well as all the contortions and fractures which we discover in its crust, and every other phenomenon supposed to necessitate catastrophes and cataclysms will be again produced.

In the massive volumes of the later editions of the *Principles of Geology* all these points are discussed and illustrated with such a wealth of facts and such cogent yet cautious reasoning as have carried conviction to all modern students. It affords us perhaps the very best proof yet given of evolution in one department of the universe—that of the surface and the crust of the earth we inhabit. Not only have all the chief modifications during an almost unimaginable period of time been clearly depicted, but they have in almost every case been shown to be the inevitable results of real and comparatively well-known causes, such as we now see at work around us.

The grand generalizations of Lyell have been strengthened since his death by more complete investigations of certain phenomena and their causes than were possible in his day; while the only objections to them seem to be founded, to some extent, upon a misconception. He has been termed a "Uniformitarian," and it is alleged that it is unphilosophical to take the limited range of causes we now see in action, as a measure of those which have acted during all past geological time. But neither Lyell nor his followers make any such assumption. They merely say, we do not find any proof of greater or more violent causes in action in past times, and we do find many indications that the great natural [16] forces then in action—seas and rivers, sun and cloud, rain and hail, frost and snow, as well as the very texture and constituents of the older rocks, and the mode in which the organisms of each age are preserved in them, must have been in their general nature and magnitude very much as they are now. Other objections, such as that the internal forces were greater when the earth was hotter, and that tidal effects must have been more powerful when the moon was nearer the earth, are altogether beside the question until we can obtain more definite measures of past time than we now possess in reference to both geological and cosmical phenomena. It may well be that the physical changes above referred to have been so slow that they would have produced no perceptibly increased effect at the epoch of the early stratified rocks. Lyell's doctrine is simply that of real against imaginary causes, and he only denies catastrophes and more violent agencies in early times, because there is no clear evidence of their actual existence, and also because known causes are quite competent to explain all geological phenomena. It must be remembered, too, that uniformitarians have never limited the natural forces of past geological periods to the precise limits of which we have had experience during the historical period. What they maintain is, that forces of the same *nature* and of the same *order of magnitude* are adequate to have brought about the evolution of the crust of the earth as we now find it.

ORGANIC EVOLUTION, ITS LAWS AND CAUSES

We now come to that branch of the subject which is the most important and distinctive of our age, and which, in popular estimation, alone constitutes evolution—the mode of origin of the innumerable species of animal and plant life which now exist or have ever existed upon the earth. [17]

The origin of the different forms of life has till quite recent times been looked upon as an almost insoluble problem, although a few advanced thinkers, even in the eighteenth century, perceived that it was probably the result of some natural process of modification or evolution; but no force or law had been set forth and established in any way adequate to produce it until the publication of Darwin's *Origin of Species*, in 1859. In the later editions of that work, Darwin has given a historical sketch of the progress of opinion on the subject. I shall, therefore, now only notice a few great writers which he has not referred to.

We have seen what an impossible and even ludicrous explanation had to be given by Lucretius; and from his day down to the middle of the eighteenth century no advance had been made. Either the problem was not referred to at all, or the theological doctrine of a special creation was held to be the only possible one. But in the middle of the eighteenth century the great French naturalist, Buffon, published his very important work, *Histoire Naturelle*, in fifteen volumes (1749–1767), in which, besides describing the characters and habits of all the animals then known, he introduced much philosophical and speculative thought, which would probably have been carried much further had he not felt obliged to conform to the religious prejudices of the age. We are indebted to Mr. Samuel Butler for having brought together all the important passages of Buffon's voluminous and now little-read works bearing upon the question of evolution, and it is from his volume that I quote.

Buffon lays stress on the great resemblance of all mammalia in internal structure, showing that the most unlike creatures may be really alike structurally. He says: "The horse, for example—what can at first sight seem more unlike mankind? Yet when we compare man and horse, point by point and detail 18 by detail, our wonder is excited rather by the resemblances than by the differences between them." He then shows that all the parts of the skeleton agree, and that it is only in proportions, the increase of some bones and the suppression of others, that they differ, adding: "If we regard the matter thus, not only the ass and the horse, but even man himself, the apes, etc., might be regarded as forming members of one and the same family." Then, after a few more illustrations, he remarks: "If we once admit that there are families of plants and animals, so that the ass may be of the family of the horse, and that the one may only differ from the other by degeneration from a common ancestor, we might be driven to admit that the ape is of the family of man, that he is but a degenerate man, and that he and man have had a common ancestor.... If it were once shown that we had right grounds for establishing these families, if the point were once gained that among plants and animals there have been even a single species which had been produced in the course of direct descent from another species, then there is no further limit to be set to the power of nature, and we should not be wrong in supposing that with sufficient time she could have evolved all other organized forms from one primordial type."

This indicates clearly enough his own opinion, but to save himself from the ecclesiastical authorities he at once adds this saving clause: "But no! It is certain, from revelation, that all animals have alike been favored with the grace of an act of direct creation, and that the first pair of every species issued full formed from the hands of the Creator."

Such examples of disarming religious prejudice are frequent, but he continually recurs to statements as to mutability which neutralize them. Here, for example, is a broad claim for nature as 19 opposed to creation. He has been showing how variable are many animals, and how changes of food, climate, and general surroundings influence both their forms and their habits; and then he exclaims:

"What cannot nature effect with such means at her disposal? She can do all except either create matter or destroy it. These two extremes of power the Deity has reserved for Himself only; creation and destruction are the action of His omnipotence. To alter and undo, to develop and renew—these are powers which He has handed over to the charge of nature."

Here we have a claim for the power of nature in the modification of species which fully comes up to the requirements of the most advanced evolutionist. It is remarkable, too, how clearly he perceived the great factors so important for the evolution of organisms, rapid multiplication, great variability, and the struggle for existence. Thus he remarks: "It may be said that the movement of nature turns upon two immovable pivots—one, the illimitable fecundity which she has given to all species; the other, the innumerable difficulties which reduce the results of that fecundity and leave throughout time nearly the same quantity of individuals in every species." Here the term "difficulties" corresponds to the "positive checks" of Malthus, and to the "struggle for existence" of Darwin; and he again and again refers to variability—as when he says: "Hence, when by some chance, common enough with nature, a variation or special feature makes its appearance, man has tried to perpetuate it by uniting together the individuals in which it has appeared."

As Buffon thus clearly understood artificial selection, thoroughly appreciated the rapid increase of all organisms, and equally well saw that their inordinate increase was wholly neutralized through such destructive agencies as hunger, disease, and enemies, and as, at the same time, he had such unbounded 20 faith in the power of nature to modify animal and vegetable forms, we feel assured that this great writer and original thinker only needed freedom to pursue this train of thought a little further and he would certainly have anticipated Darwin's great discovery of natural selection by a whole century. Even as it is we must class him as one of the great pioneers of organic evolution.

The next distinct step towards a theory of organic evolution was made by the poet Goethe at the very end of the eighteenth century, in his views of the metamorphosis of plants. He pointed out the successive modifications of the leaf which produced all the other essential parts of the higher plants—the simple cotyledons or seed leaves became modified into the variously formed leaves of the fully grown plants; these again were successively modified into the calyx, corolla, stamens, and ovary of the flower. He supposed this to be due to the increased refinement of the sap under the influence of light and air, and to indicate the steps by which the various parts of the flower had been developed. It was, therefore, a theory of evolution; but it was very unsatisfactory, inasmuch as it in no way accounted for the wonderful variety of the floral organs, or indicated any purpose served by the most prominent and conspicuous part of the flower, the highly colored and often strangely formed corolla. It was also erroneous in supposing that the corolla was a modified calyx, whereas it is now known to be a modification of the stamens.

Next came the great work of Lamarck in the first decade of the nineteenth century, in which he proposed a general system of evolution of the whole animal world. Hence he may be termed the first systematic evolutionist. His system has been rather fully described by Lyell, who, in his *Principles of Geology*, devotes a whole chapter to a summary of his doctrines; while Mr. Butler gives copious 21
quotations in three chapters of his *Evolution Old and New*; and any one who is not acquainted with the original work of Lamarck should read these two authors in order to understand how wide was his knowledge, how ingenious his explanations, and in how many important points he anticipated the views both of Lyell and Darwin. But he was half a century in advance of his age, and his only alleged causes of modification—changed conditions, use and disuse, habit and effort—were wholly insufficient to account for the vast range of the phenomena presented by the innumerable minute adaptations of living organisms to their conditions of life. He even imputed all the modifications of domestic animals to the changed conditions of food and habits to which they have been subjected by man, making no reference to the use of selection by breeders, in this respect falling short of his great predecessor, Buffon.

The general laws which Lamarck deduces from his elaborate study of nature are these:

“Firstly. That in every animal which has not passed its limit of development, the more frequent and sustained employment of any organ develops and aggrandizes it, giving it a power proportionate to the duration of its employment, while the same organ, in default of constant use, becomes insensibly weakened and deteriorated, decreasing imperceptibly in power until it finally disappears.

“Secondly. That these gains or losses of organic development, due to use or disuse, are transmitted to offspring, provided they have been common to both sexes, or to the animals from which the offspring have descended.”

The whole force of this argument depends upon the second clause—the inheritance of those individual modifications due to use and disuse. But no direct evidence of this has ever been found, 22
while there is a good deal of evidence showing that it does not occur. Again, there are many structures which cannot have been produced by use, such, for example, as the feathers of the peacock’s train, the poison in the serpent’s fangs, the hard shells of nuts, the prickly covering of many fruits, the varied armor of the turtle, porcupine, crocodile, and many others. For these reasons Lamarck’s views gained few converts; and although some of his arguments have been upheld in recent years, the fatal objections to his general principle as a means of explaining the evolution of organic forms has never been overcome.

Between the periods of Lamarck and Darwin many advances were made which clearly pointed to a general law of evolution in nature. Such were Sir William Grove’s lectures on the “Correlation of the Physical Forces,” in 1842; Helmholtz on the “Conservation of Energy,” in 1847; and Herbert Spencer’s essay on “The Development Hypothesis,” in 1852. This latter work was a complete and almost unanswerable argument for a natural process of continuous evolution of the whole visible universe, including organic nature, man, and social phenomena. It is further extended in the later editions of the author’s *First Principles*, which, as a coherent exposition of philosophy, co-ordinating and explaining all human knowledge of the universe into one great system of evolution everywhere

conforming to the same general principles, must be held to be one of the greatest intellectual achievements of the nineteenth century. It left, however, the exact method of evolution of organisms untouched, and thus failed to account for those complex adaptations and appearances of design in the various species of animals and plants which have always been the stronghold of those who advocated special creation. This difficulty was met by Darwin's theory of *The Origin of Species by Means of* 23
Natural Selection, published in 1859, and the series of works that succeeded it; and to a brief sketch of this theory the remainder of our space must be devoted.

THE THEORY OF "NATURAL SELECTION"

Although, as we have seen, a succession of great writers and thinkers had for more than half a century shown the necessity for some process of evolution as the only rational or intelligible mode of origin of existing species of animals and plants, as well as of the whole physical universe, yet these views were by no means generally accepted by the educated classes, while few bodies of students were less influenced by them than zoologists and botanists, generally known as naturalists.

Now, Darwin wrote especially for these classes, and no one knew better than he did their great prejudice on this matter. Not only had such men as Sir Charles Lyell and Sir John Herschel expressed themselves strongly against all theories of the transmutation of species, but the universal contempt and indignation of naturalists as well as theologians against *The Vestiges of Creation*, published anonymously a few years earlier, and giving a most temperate and even religious exposition of the general arguments for the universality of evolution, showed what any one might expect who advocated and attempted to demonstrate a similar theory. This accounts for Darwin writing to Sir Joseph Hooker, in 1844, of his being "almost convinced that species are not (it is like confessing a murder) immutable," and again, in 1845, to the Rev. L. Blomefield, that he now saw the way in which new varieties become exquisitely adapted to the external conditions of life and to other surrounding beings, and he adds: "I am a bold man to lay myself open to being thought a complete fool, and a most deliberate one." It is only by a consideration of the frame of mind of even advanced thinkers at the 24
time Darwin was preparing his work, and remembering how small was the effect which had been produced by Buffon, Goethe, Lamarck, the author of *Vestiges of Creation*, and the earlier writings of Herbert Spencer, that we can adequately realize the marvellous work that he accomplished. Let us now briefly consider the essential nature of this new theory, which in a few brief years became the established belief of the great majority of the students of nature, and which also gave a new interest in nature to the whole thinking world.

The theory of natural selection is founded upon a few groups of thoroughly ascertained and universally admitted facts, with the direct and necessary results of those facts.

The first group of facts consists of the great powers of increase of all organisms and the circumstance that, notwithstanding this great yearly increase, the actual population of each species remains stationary, there being no permanent increase. Now, these two facts were recognized by Buffon, but though, of course, known to all subsequent writers, were fully appreciated or thought out to their logical results by none of them. Lamarck, so far as I can ascertain, took no notice of them whatever. Darwin has given illustrations of these facts in Chapter IV. of the *Origin of Species*, and I have added others in the second chapter of my *Darwinism*. That the population of each species remains stationary, with, of course, considerable fluctuations, is both a matter of observation and of reasoning. The powers of increase of all creatures are so great that if there is in any country room and food for a larger number of any species they will be produced in a year or two. It is impossible, therefore, to believe that, in a state of nature, where all kinds of animals and plants have lived together as they best could for thousands of years, there can be any important difference in their numbers from 25
year to year or from century to century.

Now, it is as a consequence of these two indisputable facts that the struggle for existence necessarily results. For if every year each pair of animals or each plant produces only ten young animals or plants, and this is very far below the average, and if the adult life of these is taken at ten years, again below the average of the higher plants and animals, then, unless some of the parents die, the whole of the offspring must die off every year; or, in other words, only as many young can survive as are necessary to replace the old ones that die. Hence the deaths must always (on the average and in the long run) equal the births. This terrible yearly destruction is an absolutely certain fact, as well as an inevitable result of the two preceding facts, and it is said to be due to the struggle for existence. This struggle is manifold in its nature. Individuals of the same species struggle together for food, for light, for moisture; they struggle also against other species having the same wants; they struggle against every kind of enemy, from parasitic worms and insects up to carnivorous animals; and there is a continual struggle with the forces of nature—frosts, rains, droughts, floods, and tempests.

These varied causes of destruction may be seen constantly at work by any one who looks for them. They act from the moment of birth, being more especially destructive to the young; and, as only one in ten or fifty or a thousand (according to the rate of increase of the particular species) can possibly come to the full breeding age, we feel compelled to ask ourselves: What determines the nine or the forty-nine or the nine hundred and ninety-nine, as the case may be, which die, and the one which survives? Darwin calls this process of extermination one of "natural selection"—that is, by this process nature weeds out the weak, the unhealthy, the unadapted, the imperfect in any way. Of course, 26
what may be called chance or accident produces many deaths of individuals otherwise well fitted to live, but if we think of the process going on day by day and year by year till only one in a hundred of those born in a given area are left alive, it is impossible to suppose that the *one* which has passed through all the dangers and risks which have been fatal to, say, his ninety-nine relations was not, in all the faculties and qualities essential to the continuance of the race, decidedly better organized than the bulk of those which succumbed. Herbert Spencer calls the process the "survival of the fittest," and though the term may not be strictly accurate in the case of any one species in any one year, yet when we consider that the struggle is going on *every* year, during the whole duration of each species, we cannot doubt that, on the whole, and in the long run, those which survive are among the fittest. The struggle is so severe, so incessant, that the smallest defect in any sense organ, any physical weakness, any imperfection in constitution, will almost certainly, at one time or another, be fatal.

This continual weeding out of the less fit, in every generation, and with exceptional severity in recurring adverse seasons, will produce two distinct effects, which require to be clearly distinguished. The first is the preservation of each species in the highest state of adaptation to the conditions of its existence; and, therefore, so long as these conditions remained unchanged, the effect of natural selection is to keep each well-adapted species also unchanged. The second effect is produced whenever the conditions vary, when, taking advantage of the variations continually occurring in all well-adapted and therefore populous species, the same process will slowly but surely bring about complete adaptation to the new conditions. And here another fact—the normal variability of all populous or dominant species, which is seldom realized except by those who have largely and 27
minutely compared the individuals of many species in a state of nature—comes into play. There are some writers who admit all the preceding facts and reasoning, so far as the action of natural selection in weeding out the unfit and thus keeping every species in the highest state of efficiency is concerned, but who deny that it can modify them in such a way as to adapt them to new conditions, because they allege that "the right variations will not always occur at the right time." This seems a strong and real objection to many of their readers, but to those who have studied the variability of species in nature, it is a mere verbal difficulty dependent on ignorance of the actual facts. A brief statement of the facts must therefore be given.

Of late years, and chiefly since Darwin's works were written, the variability of animals and plants in a state of nature has been carefully studied, by actual comparison and measurement of scores, hundreds, and even thousands of individuals of many common, that is, abundant and widely distributed species; and it is found that in almost every case they vary greatly, and, what is still more important, that every organ and every appendage varies independently and to a large amount. Some of the best known of these facts of variation are adduced in my *Darwinism*, and are illustrated by numerous diagrams, and much more extensive series have since been examined, always with the same general result. By large variability is meant a variation of from ten to twenty-five per cent. on each side of the mean size, this amount of variation occurring in at least five or ten per cent. of the whole number of individuals, and in every organ or part as yet examined, external or internal.

Now, as the weeding-out process is so severe, only from one in ten to one in a hundred of those born surviving to produce young, the above proportion of variations affords ample scope for the [28] selection of any variation needed in order to modify the species so as to bring it into harmony with new or changing conditions. And this will be the more easy and certain if we consider how slowly land-surfaces and climates undergo permanent changes; and these are certainly the kind of changes that initiate and compel alterations, first, perhaps, in the distribution, and afterwards in the structure and habits of species. It follows, therefore, as an absolutely necessary conclusion from the facts, if natural selection can and does keep each continually varying species in close adaptation to an unchanging environment, that it preserves the fixity of its mean or average condition, and almost every objector admits this. Then, given a slowly changing environment, the same power must inevitably bring about whatever corresponding change is needed for the well-being and permanent survival of the various species which are subjected to those changed conditions.

I shall not add here a further consideration of the objections and difficulties alleged by critics of the theory. All of these have, I believe, been fully answered either by Darwin or myself, many of the most recent having been discussed in review articles. Suffice it to say here that this theory of natural selection—meaning the elimination of the least fit, and therefore the ultimate "survival of the fittest"—has furnished a rational and precise explanation of the means of adaptation of all existing organisms to their conditions, and therefore of their transformation from the series of distinct but allied species which occupied the earth at some preceding epoch. In this sense it has actually demonstrated the "origin of species," and, by carrying back this process step by step into earlier and earlier geological times, we are able mentally to follow out the evolution of all forms of life from one or a few primordial forms. Natural selection has thus supplied that motive power of change and adaptation that was wanting in all earlier attempts at explanation, and this has led to its very general acceptance [29] both by naturalists and by the great majority of thinkers and men of science.

The brief sketch now given of the progress of human thought on the questions of the fact and the mode of the evolution of the material universe indicates how great has been the progress during the nineteenth as compared with all preceding centuries.

Although the philosophical writers of classical times obtained a few glimpses of the action of law in nature regulating its successive changes, nothing satisfactory could be effected till the actual facts had been better ascertained by the whole body of workers who, during the last five centuries, have penetrated ever more and more deeply into nature's mysteries and laws. By their labors we became possessed of such a body of carefully observed facts that, towards the end of the eighteenth century, such thinkers as Laplace and Hutton were enabled to give us the first rudiments of theories of evolution as applied to the solar system and the earth's crust, both of which have been greatly developed and rendered more secure during the century just passed away.

In like manner Buffon and Goethe may be said to have started the idea of organic evolution, more systematically treated a little later by Lamarck, but still without any discovery of laws adequate to produce the results we see everywhere in nature. The subject then languished, till, after twenty years of observation and research, Charles Darwin produced a work which at once satisfied many thinkers that the long-desired clew had been discovered. Its acceptance by almost the whole scientific world soon followed: it threw new light on almost every branch of research, and it will probably take its place, in the opinion of future generations, as the crowning achievement of the nineteenth century.

ALFRED RUSSEL WALLACE.

CHEMISTRY

The progress of the science of chemistry forms one phase of the progress of human thought. While at first mankind was contented to observe certain phenomena, and to utilize them for industrial purposes, if they were found suitable, "philosophers," as the thinking portion of our race loved to call themselves, have always attempted to assign some explanation for observed facts, and to group them into similars and dissimilars. It was for long imagined, following the doctrines of the Greeks and of their predecessors, that all matter consisted of four elements or principles, names which survive to this day in popular language. These were "fire," "air," "water," and "earth." It was not until the seventeenth century that Boyle in his *Sceptical Chymist* (1661) laid the foundations of the modern science, by pointing out that it was impossible to explain the existence of the fairly numerous chemical substances known in his day, or the changes which they can be made to undergo, by means of the ancient Greek hypotheses regarding the constitution of matter. He laid down the definition of the modern meaning of the word "element"; he declined to accept the current view that the properties of matter could be modified by its assimilating the qualities of fire, air, earth, or water, and he defined an element as the *constituent* of a compound body. The first problem, then, to be solved, was to determine which of the numerous forms of matter were to be regarded as elementary, and which are compound, or composed of two or more elements in a state of combination; and to produce such compounds by 34
causing the appropriate elements to unite with each other.

One of the first objects to excite curiosity and interest was the air which surrounds us, and in which we live and move and have our being. It was, however, endowed with a semi-spiritual and scarcely corporeal nature in the ideas of our ancestors, for it does not affect the senses of sight, smell, or taste, and though it can be felt, yet it eludes our grasp. The word "gas," moreover, was not invented until Van Helmont devised it to designate various kinds of "airs" which he had observed. The important part which gases play in the constitution of many chemical compounds was accordingly overlooked; and, indeed, it appeared to be almost as striking a feat of necromancy to produce a quantity of a gas of great volume from a small pinch of solid powder as for a "Jinn" of enormous stature but of delicate texture to issue from a brass pot, as related in the *Arabian Nights Entertainments*. Gradually, however, it came to be recognized, not merely that gases have corporeal existence, but that they even possess weight. This, though foreshadowed by Torricelli, Jean Rey, and others, was first clearly proved by Black, professor of chemistry in Edinburgh, in 1752, through his masterly researches, as carbonic acid.

The ignorance of the material nature of gases and of their weight lies at the bottom of the "Phlogistic Theory," a theory devised by Stahl about the year 1690, to account for the phenomena of combustion and respiration and the recovery or "reduction" of metals from their "earths" by heating with charcoal or allied bodies. According to this inverted theory, a substance capable of burning was imagined to contain more or less phlogiston, a principle which it parted with on burning, leaving an earth deprived of phlogiston, or "dephlogisticated," behind if a metal. This earth, when heated with substances rich in phlogiston, such as coal, wood, flour, and similar bodies, recovered the phlogiston, 35
which it had lost on burning, and, with the added phlogiston, its metallic character. Other substances, such as phosphorus and sulphur, gave solids or acid liquids, to which phlogiston was not so easy to add; but even they could be rephlogisticated. On this hypothesis, it was the earths, and such acid liquids as sulphuric or phosphoric acids, which were the elements; the metals and sulphur and phosphorus were their compounds with phlogiston.

The discovery of oxygen by Priestley and by Scheele in 1774, and the explanation of its functions by Lavoisier during the following ten years, gave their true meaning to these phenomena. It was then recognized that combustion was union with oxygen; that an "earth" or "calx" was to be regarded as the compound of a metal with oxygen; that when a metal becomes tarnished, and converted into such an earthy powder, it is being oxidized; that this oxide, on ignition with charcoal or carbon, or with compounds such as coal, flour, or wood, of which carbon is a constituent, gives up its oxygen to the carbon, forming an oxide of carbon, carbonic oxide on the one hand, or carbonic "acid" on the other, while the metal is reproduced in its "reguline" or metallic condition, and that the true elements are metals, carbon, sulphur, phosphorus, and similar bodies, and not the products of their oxidation.

The discovery that air is in the main a mixture of nitrogen, an inert gas, and oxygen, an active one, together with a small proportion of carbonic "acid" (or, as it is now termed, anhydride)—a discovery perfected by Rutherford, Black, and Cavendish—and that water is a compound with oxygen of hydrogen, previously known as inflammable air, by Cavendish and by Watt, finally overthrew the theory of phlogiston; but at the beginning of this century it still lingered on, and was defended by [36] Priestley until his death in 1804. Such, in brief, was the condition of chemical thought in the year 1800. Scheele had died in 1786, at the early age of forty-four; Lavoisier was one of the victims of the French Revolution, having been guillotined in 1794; Cavendish had ceased to work at chemical problems, and was devoting his extraordinary abilities to physical problems of the highest importance, while living the life of an eccentric recluse, and Priestley, driven by religious persecution from England to the more tolerant shores of America, was enjoying a peaceful old age, enlivened by occasional incursions into the region of sectarian controversy.

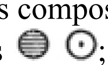
The first striking discovery of our century was that of the compound nature of the alkalies and of the alkaline earths. This discovery was made by Humphry Davy. Born in Cornwall in 1778, he began the study of chemistry, self-taught, in 1796; and in 1799 he became director of the "Pneumatic Institution," an undertaking founded by Dr. Beddoes, at Bristol, for the purpose of experiments on the curative effects of gases in general. Here he at once made his mark by the discovery of the remarkable properties of "laughing gas," or nitrous oxide. At the same time he constructed a galvanic battery, and began to perform experiments with it in attempting to decompose chemical compounds by its means. In 1801 Davy was appointed professor of chemistry at the Royal Institution, a society or club which had been founded a few years previously by Benjamin Thompson, Count Rumford, for the purpose of instructing and amusing its members with recent discoveries in chemistry and natural philosophy. In 1807 Davy applied his galvanic battery to the decomposition of damp caustic potash and soda, using platinum poles. He was rewarded by seeing globules of metal, resembling mercury in appearance, at the negative pole; and he subsequently proved that these globules, when burned, reproduced the alkali [37] from which they had been derived. They also combined with "oxymuriatic acid," as chlorine (discovered by Scheele) was then termed, forming ordinary salt, if sodium be employed, and the analogous salt, "muriate of potash," if the allied metal, potassium, were subjected to combustion. By using mercury as the negative pole, and passing a current through a strong solution of the chloride of calcium, strontium, or barium, Davy succeeded in procuring mixtures with mercury or "amalgams" of their metals, to which he gave the names calcium, strontium, and barium. Distillation removed most of the mercury, and the metal was left behind in a state of comparative purity. The alkali metals, potassium and sodium, were found to attack glass, liberating "the basis of the silex," to which the name silicon has since been given.

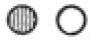
Thus nearly the last of the "earths" had been decomposed. It was proved that not merely were the "calces" of iron, copper, lead, and other well-known metals compounds of the respective metals with oxygen, but Davy showed that lime, and its allies, strontia and baryta, and even silica or flint, were to be regarded as oxides of elements of metallic appearance. To complete our review of this part of the subject, suffice it to say that aluminum, a metal now produced on an industrial scale, was prepared for the first time in 1827 by Wöhler, professor of chemistry at Göttingen, by the action of potassium on its chloride, and alumina, the earthy basis of clay, was shown to be the oxide of the metal aluminum. Indeed, the preparation of this metal in quantity is now carried out at Schoffhausen-on-the-Rhine and at the Falls of Foyers, in Scotland, by electrolysis of the oxide dissolved in melted cryolite, a mineral consisting of the fluorides of sodium and aluminum, by a method differing only in scale from that by means of which Davy isolated sodium and potassium in 1806.

To Davy, too, belongs the merit of having dethroned oxygen from its central position among the elements. Lavoisier gave to this important gas the name “oxygen,” because he imagined it to be the constituent of all acids. He renamed the common compounds of oxygen in such a manner that the term oxygen was not even represented in the name—only inferred. Thus a “nitrate” is a compound of an oxide of nitrogen and an oxide of a metal; a “sulphate,” of the oxide of a metal with one of the oxides of sulphur, and so on. Davy, by discovering the elementary nature of chlorine, showed, first, that it is not an oxide of hydrochloric acid (or muriatic acid as it was then called); and, second, that the latter acid is the compound of the element chlorine with hydrogen. This he did by passing chlorine over white-hot carbon—a substance eminently suited to deprive oxy-compounds of their oxygen—and proving that no oxide of carbon is thereby produced; by acting on certain chlorides, such as those of tin or phosphorus with ammonia, and showing that no oxide of tin or phosphorus is formed; and, lastly, by decomposing “muriatic acid gas” (gaseous hydrogen chloride) with sodium, and showing that the only product besides common salt is hydrogen. Instead, therefore, of the former theory that a chloride was a compound of the unknown basis of oxymuriatic acid with oxygen and the oxide of a metal, he introduced the simpler and correct view that a chloride is merely a compound of the element chlorine with a metal. In 1813 he established the similar nature of fluorine, pointing out that on the analogy of the chlorides it was a fair deduction that the fluorides are compounds of an undiscovered element, fluorine, with metals; and that hydrofluoric acid is the true analogue of hydrochloric acid. The truth of this forecast has been established of recent years by Henri Moissan, who isolated gaseous fluorine by subjecting a mixture of hydrofluoric acid and hydrogen potassium fluoride contained in a platinum U tube to the action of a powerful electric current. He has recently found that the tube may be equally well constructed of copper; and this may soon lead to the industrial application of the process. The difficulty of isolating fluorine is due to its extraordinary chemical energy; for there are few substances, elementary or compound, which resist the action of this pale yellow, suffocating gas. In 1811 iodine, separated by Courtois from the ashes of sea-plants, was shown by Davy to be an element analogous to chlorine. Gay-Lussac subsequently investigated it and prepared many of its compounds; and in 1826 the last of these elements, bromine, was discovered in the mother-liquor of sea-salt by Balard. The elements of this group have been termed “halogens,” or “salt producers.” [38] [39]

While Davy was pouring his researches into the astonished ears of the scientific and dilettante world, John Dalton, a Manchester school-master, conceived a theory that has proved of the utmost service to the science of chemistry, and which bids fair to outlast our day. It had been noticed by Wenzel, by Richter, by Wollaston, and by Cavendish, towards the end of the last century, that the same compounds contain the same constituents in the same proportions, or, as the phrase runs, “possess constant composition.” Wollaston, indeed, had gone one step farther, and had shown that when the vegetable acid, oxalic acid, is combined with potash, it forms two compounds, in one of which the acid is contained in twice as great an amount relatively to the potash as in the other. The names *monoxalate* and *binoxalate* of potash were applied to these compounds, to indicate the respective proportions of the ingredients. Dalton conceived the happy idea that by applying the ancient Greek conception of atoms to such facts the relative weights of the atoms could be determined. Illustrating his views with the two compounds of carbon with hydrogen, marsh gas and olefiant gas, and with the two acids of carbon, carbonic oxide, carbonic “acid,” he regarded the former as a compound of one atom of carbon and one of hydrogen, and the second as a compound of one atom of carbon and two of hydrogen, and similarly for the two oxides of carbon. Knowing the relative weights in which these elements enter into combination, we can deduce the relative weights of the atoms. Placing the relative weight of an atom of hydrogen equal to unity, we have: [40]

	Marsh Gas	Olefiant Gas		Carbonic Oxide	Carbonic Acid
Carbon	6	6	Carbon	5	6
Hydrogen	1	2	Oxygen	8	16

Thus the first compound, marsh gas, was regarded by Dalton as composed of an atom of carbon in union with an atom of hydrogen; or, to reproduce his symbols, as ; while the second, olefiant

gas, on this hypothesis, was a compound of two atoms of hydrogen with one of carbon, or . Similarly the symbols , and  were given to the two compounds of carbon with oxygen. So water was assigned the symbol , for Dalton imagined it to be a compound of one atom of hydrogen with one of oxygen. Compounds containing only two atoms were termed by him "binary"; those containing three, "ternary"; four, "quaternary," and so on. The weight of an atom of oxygen was eight times that of an atom of hydrogen; while that of an atom of carbon was six times as great as the unit. By assigning symbols to the elements, consisting of the initial letters of their names, or of the first two letters, formulas were developed, indicating the composition of the compound, the atomic weights of the elements being assured. Thus, NaO signified a compound of an atom of sodium (natrium), weighing twenty-three times as much as a similar atom of hydrogen, with an atom of 41
oxygen, possessing eight times the weight of an atom of hydrogen. Therefore, thirty-one pounds of soda should consist of twenty-three pounds of sodium in combination with eight pounds of oxygen, for, according to Dalton, each smallest particle of soda contains an atom of each element, and the proportion is not changed, however many particles be considered.

It has been pointed out by Judge Stallo, of Philadelphia, in his *Concepts of Physics*, that such a hypothesis as that of Dalton is no explanation; that a fact of nature, as, for example, the fact of simple and multiple proportions, is not *explained* by being minified. Allowing the general truth of this statement, it is, nevertheless, undoubted that chemistry owes much to Dalton's hypothesis—a lucky guess at first, it represents one of the fundamental truths of nature, although its form must be somewhat modified from that in which Dalton conceived it. Dalton's work was first expounded by Thomas Thomson, professor at Glasgow, in his *System of Chemistry*, published in 1805; and subsequently in Dalton's own *New System of Chemical Philosophy*, the three volumes of which were published in 1808, in 1810, and in 1827.

The determination of these "Constants of Nature" was at once followed out by many chemists, Thomson among the first. But chief among the chemists who have pursued this branch of work was Jacob Berzelius, a Swede, who devoted his long life (1779–1848) to the manufacture of compounds, and to the determination of their composition, or, as it is still termed, the determination of the "atomic weights"—more correctly, "equivalents"—of the elements of which they are composed. It is to him that we owe most of our analytical methods, for, prior to his time, there were few, if any, accurate analyses. Although Lavoisier had devised a method for the analysis of compounds of carbon, viz., by 42
burning the organic compounds in an atmosphere of oxygen contained in a bell-jar over mercury, and measuring the volume of carbon dioxide produced, as well as that of the residual oxygen, Berzelius achieved the same results more accurately and more expeditiously by heating the substance, mixed with chlorate of potassium and sodium chloride, and then estimating the hydrogen as well as the carbon; this process was afterwards perfected by Liebig. Berzelius, however, was able to show that compounds of carbon, like those of other elements, were instances of combination in constant and in multiple proportions.

In 1815 two papers were published in the *Annals of Philosophy* by Dr. Prout, which have had much influence on the progress of chemistry. They dealt with the figures which were being obtained by Thomson, Berzelius, and others, at that time supposed to represent the "atomic weights" of the elements. Prout's hypothesis, based on only a few numbers, was that the atomic weights of all elements were multiples of that of hydrogen, taken as unity. There was much dispute regarding this assertion at the time, but as it was contradicted by Berzelius's numbers, the balance of opinion was against it. But about the year 1840 Dumas discovered an error in the number (12.12) given by Berzelius as the atomic weight of carbon; and with his collaborator, Stas, undertook the redetermination of the atomic weights of the commoner elements—for example, carbon, oxygen, chlorine, and calcium. This line of research was subsequently pursued alone by Stas, whose name will always be remembered for the precision and accuracy of his experiments. At first Dumas and Stas inclined to the view that Prout's hypothesis was a just one, but it was completely disproved by Stas's subsequent work, as well as by that of numerous other observers. It is, nevertheless, curious that a 43
much larger proportion of the atomic weights approximate to whole numbers than would be foretold

by the doctrine of chances, and perhaps the last has not been heard of Prout's hypothesis, although in its original crude form it is no longer worthy of credence.

One of the most noteworthy of the discoveries of the century was made by Gay-Lussac (1778–1850) in the year 1808. In conjunction with Alexander von Humboldt, Gay-Lussac had rediscovered about three years before what had previously been established by Cavendish—namely, that, as nearly as possible, two volumes of hydrogen combine with one volume of oxygen to form water, the gases having been measured at the same temperature and pressure. Humboldt suggested to Gay-Lussac that it would be well to investigate whether similar simple relations exist between the volumes of other gaseous substances when they combine with each other. This turned out to be the case; it appeared that almost exactly two volumes of carbonic oxide unite with one volume of oxygen to form carbon dioxide; that equal volumes of chlorine and hydrogen unite to form hydrochloric acid gas; that two volumes of ammonia gas consist of three volumes of hydrogen in union with one volume of nitrogen, and so on. From such facts, Gay-Lussac was led to make the statement that: The weights of equal volumes of both simple and compound gases, and therefore their densities, are proportional to their empirically found combining weights, or to rational multiples of the latter. Gay-Lussac recognized this discovery of his to be a support for the atomic theory; but it did not accord with many of the then received atomic weights. The assumption that equal volumes of gases contain equal numbers of particles, or, as they were termed by him, *molécules intégrantes*, was made in 1811 by Avogadro, professor of physics at Turin (1776–1856). This theory, which has proved of the utmost importance to the sciences both of physics and of chemistry, had no doubt occurred to Gay-Lussac, and had been 44
rejected by him for the following reasons: A certain volume of hydrogen, say one cubic inch, may be supposed to contain an equal number of particles (atoms) as an equal volume of chlorine. Now these two gases unite in equal volumes. The deduction appears so far quite legitimate that one atom of hydrogen has combined with one atom of chlorine. But the resulting gas occupies two cubic inches, and must therefore contain the same number of particles of hydrogen chloride, the compound of the two elements, as one cubic inch originally contained of hydrogen, or of chlorine. Thus we have two cubic inches containing, of uncombined gases, twice as many particles as is contained in that volume, after combination. Avogadro's hypothesis solved the difficulty. By premising two different orders of particles, now termed *atoms* and *molecules*, the solution was plain. According to him, each particle, or molecule, of hydrogen is a complex, and contains two atoms; the same is the case with chlorine. When these gases combine, or rather *react*, to form hydrogen chloride, the phenomenon is one of a change of partners; the molecule, the double atom, of hydrogen splits; the same is the case with the molecule of chlorine; and each liberated atom of hydrogen unites with a liberated atom of chlorine, forming a compound, hydrogen chloride, which equally consists of a molecule, or double atom. Thus two cubic inches of hydrogen chloride consist of a definite number of molecules, equal in number to those contained in a cubic inch of hydrogen, plus those contained in a cubic inch of chlorine. The case is precisely similar, if other compounds of gases be considered.

Berzelius was at first inclined to adopt this theory, and indeed went so far as to change many of his atomic weights to make them fit it. But later he somewhat withdrew from his position, for it appeared to him that it was hazardous to extend to liquids and solids a theory which could be held only 45
of gases. Avogadro's suggestion, therefore, rested in abeyance until the publication, in 1858, by Cannizzaro, now professor of chemistry in Rome, of an essay in which all the arguments in favor of the hypothesis were collected and stated in a masterly manner. It will be advisable to revert to this hypothesis at a later point, and to consider other guides for the determination of atomic weights.

In 1819, Dulong (1785–1838), director of the Ecole Polytechnique at Paris, and Petit (1791–1820), professor of physics there, made the discovery that equal amounts of heat are required to raise equally the temperature of solid and liquid elements, provided quantities are taken proportional to their atomic weights. Thus, to raise the temperature of 56 grammes of iron through one degree requires approximately the same amount of heat as is required to raise through one degree 32 grammes of sulphur, 63.5 grammes of copper, and so on; these numbers representing the atomic weights of the elements named. In other words, *equal numbers of atoms have equal capacity for heat*. The number of heat units, or calories (one calory is the amount of heat required to raise the temperature of 1 gramme of water through 1° C.), which is necessary to raise the atomic weight expressed in grammes of any

solid or liquid element through 1° C. is approximately 6.2; it varies between 5.7 and 6.6 in actual part. This affords a means of determining the true value of the atomic weight of an element, as the following example will show: The analysis of the only compound of zinc and chlorine shows that it contains 47.49 per cent. of zinc and 52.16 per cent. of chlorine. Now one grain of hydrogen combines with 35.5 grains of chlorine to form 36.5 grains of hydrogen chloride; and, as already remarked, one volume of hydrogen and one volume of chlorine combine, forming two volumes of hydrogen chloride. 46
Applying Avogadro's hypothesis, one molecule of hydrogen and one molecule of chlorine react to yield two molecules of hydrogen chloride; and as each molecule is supposed to consist in this case of two atoms, hydrogen chloride consists of one atom of each of its constituent elements. The amount of that element, therefore, which combines with 35.5 grains of chlorine may give the numerical value of the atomic weight of the element, if the compound contains one atom of each element; in that case the formula of the above compound would be zinc, and the atomic weight of zinc, 32.7; but if the formula is $ZuCl_3$, the atomic weight of zinc would be 32.7 × 2; if $ZuCl_3$, 32.7 × 3, and so on. The specific heat of metallic zinc enables this question to be solved. For it has been found, experimentally, to be about 0.095; and 6.2 ÷ 0.095 = 65.2, a close approximation to 32.7 × 2 = 65.4. The conclusion is therefore drawn that zinc chloride is composed of one atom of zinc in combination with two atoms of chlorine, that the atomic weight of zinc is 65.4, and that the molecular weight of zinc chloride is 65.4 + (35.5 × 2) = 136.4. Inasmuch as the relative weight of a molecule of hydrogen is 2 (that of an atom being 1), zinc chloride in the gaseous state should be 136.4 ÷ 2 = 68.2 times that of hydrogen, measured at the same temperature and pressure. This has been found, experimentally, to be the case.

The methods of determining the vapor densities, or relative weights of vapors, are three in number; the first method, due to Dumas (1827), consists in vaporizing the substance in question in a bulb of glass or of porcelain, at a known temperature, closing the bulb while still hot, and weighing it after it is cold. Knowing the capacity of the bulb, the weight of hydrogen necessary to fill it at the desired temperature can be calculated, and the density of the vapor thus arrived at. A second method was devised by Gay-Lussac and perfected by A. W. Hofmann (1868); and a third, preferable for its 47
simplicity and ease of execution, is due to Victor Meyer (1881).

In 1858, as already remarked, Cannizzaro showed the connection between these known facts, and for the first time attention was called to the true atomic weights, which were, up to that time, confused with equivalents, or weights of elements required to replace one unit weight of hydrogen. These were generally regarded as atomic weights by Dalton and his contemporaries.

Some exceptions had been observed to the law of Dulong and Petit, viz., beryllium, or glucinium, an element occurring in emeralds; boron, of which borax is a compound; silicon, the component of quartz and flint, and carbon. It was found by Weber that at high temperatures the specific heats of these elements are higher, and the atomic heats approximate to the number of 6.2; but this behavior is not peculiar to these elements, for it appears that the specific heat of all elements increases with rise of temperature.

A certain number of exceptions have also been noticed to the law of Gay-Lussac, which may be formulated: the molecular weight of a compound in a gaseous state is twice its density referred to hydrogen. Thus equal volumes of ammonia and hydrogen chloride unite to form ammonium chloride. It was to be expected that the density should be half the molecular weight, thus:

$$\underset{(14+3)}{NH_3} + \underset{(1+35.5)}{HCl} = \underset{53.5}{NH_4Cl}; \text{ and } 53.5 \div 2 = 26.75 = \text{density.}$$

But the density actually found is only half that number, viz., 13.37; and for long this and similar cases were supposed to be exceptions to the law of Gay-Lussac, viz., that equal volumes of gases at the same pressure expand equally for equal rise of temperature. In other instances the gradual decrease in density with rise of temperature can be followed, as with chloral hydrate, the products of which are 48
chloral and water.

It was recognized by St. Claire Deville (1857) that the decrease in density of such mixtures of gases was due, not to their being exceptions to Avogadro's law, but to the gradual decomposition of the compound body with rise of temperature. To this gradual decomposition he gave the name *dissociation*. This conception has proved of the utmost importance to the science, as will be seen in the sequel. To take the above instance of ammonium chloride, its abnormal density is due to its dissociation into ammonia and hydrogen chloride; and the gas which is obtained on raising its temperature consists, not of gaseous ammonium chloride, but of a mixture of ammonia and hydrogen chloride, which, as is easily seen, occupy, when separate, twice the volume that would be occupied by the gaseous compound. Of recent years it has been shown by Brereton Baker that, if perfectly free from moisture, ammonium chloride gasifies as such, and that its density in the state of vapor is, in fact, 26.75.

The molecular complexity of gases has thus gradually become comprehended, and the truth of Avogadro's law has gained acceptance. And as a means of picturing the behavior of gaseous molecules, the "Kinetic Theory of Gases" has been devised by Joule, Clausius, Maxwell, Thomson (Lord Kelvin), and others. On the assumption that the pressure of a gas on the walls of the vessel which contains it is due to the continued impacts of its molecules, and that the temperature of a gas is represented by the product of the mass of the molecules, or the square of their velocity, it has been possible to offer a mechanical explanation of Boyle's law, that at constant temperature the volume of a gas diminishes in proportion as the pressure increases; of Gay-Lussac's law, that all gases expand equally for equal rise of temperature, provided pressure is kept constant; the condition being that equal 49 volumes of gases contain equal numbers of molecules. A striking support is lent to this chain of reasoning by the facts discovered by Thomas Graham (1805–1869), professor at University College, London, and subsequently master of the Royal Mint. Graham discovered that the rate of diffusion of gases into each other is inversely as the square roots of their densities. For instance, the density of hydrogen being taken as unity, that of oxygen is sixteen times as great; if a vessel containing hydrogen be made to communicate with one containing oxygen, the hydrogen will pass into the oxygen and mix with it; and, conversely, the oxygen will pass into the hydrogen vessel. This is due to the intrinsic motion of the molecule of each gas. And Graham found, experimentally, that for each volume of oxygen which enters the hydrogen vessel four volumes of hydrogen will enter the oxygen vessel. Now, $4 = \sqrt{16}$; and as these masses are relatively 1 and 16, and their temperatures are equal, the square of their velocities are respectively 1 and 16.

The question of the molecular complexity of gases being thus disposed of, it remains to be considered what are the relative complexity of liquid molecules. The answer is indicated by a study of the capillary phenomena of liquids, one method of measuring which is the height of their ascent in narrow or capillary tubes. We shall not enter here into detail as to the method and arguments necessary; suffice it to say that the Hungarian physicist Eötvös was the first to indicate the direction of research, and that Ramsay and Shields succeeded in proving that the complexity of the molecules of most liquids is not greater than that of the gases which they form on being vaporized; and also that certain liquids, *e.g.*, water, the alcohols, and other liquids, are more or less "associated," *i.e.*, their molecules occur in couplices of two, three, four, or more, and as the temperature is raised the 50 complexity of molecular structure diminishes.

As regards the molecular complexity of solids, nothing definite is known, and, moreover, there appears to be no method capable of revealing it.

While the researches of which a short account has now been given have led to knowledge regarding the nature of molecules, the structure of the molecule has excited interest since the early years of the century, and its investigation has led to important results. The fact of the decomposition of acidified water by an electric current, discovered by Nicholson and Carlisle, and of salts into "bases" and "acids" by Berzelius and Hisinger in 1803, led to the belief that a close connection exists between electric energy, or, as it was then termed, "electric force," and the affinity which holds the constituents of chemical compounds in combination. In 1807 Davy propounded the theory that all compounds consist of two portions, one electro-positive and the other electro-negative. This idea was the result of experiments on the behavior of substances, such, for example, as copper and sulphur—if portions of these elements be insulated and then brought into contact they become oppositely electrified. The degree of electrification is intensified by rise of temperature until, when combination ensues, the

electrification vanishes. Combination, therefore, according to Davy, is concurrent with the equalization of potentials. In 1812 Berzelius brought forward an electro-chemical theory which for the following twenty years was generally accepted. His primary assumption was that the atoms of elements, or, in certain cases, groups of atoms, are themselves electrified; that each atom, or group of atoms, possesses two poles, one positive, the other negative; that the electrification of one of these poles predominates over that of the other, so that the atom or group is itself, as a whole, electro-positive, or electro- 51
negative; that combination ensued between such oppositely electrified bodies by the neutralization, partial or complete, of their electric charges; and, lastly, that the polarity of an element or group could be determined by noting whether the element or group separated at the positive or at the negative pole of the galvanic battery, or electrolysis. For Berzelius, oxygen was the most electro-negative and potassium the most electro-positive of the elements, the bridge between the "non-metals" and the "metals" being hydrogen, which, with nitrogen, forms a basic, or electro-positive, group, while with chlorine, etc., it forms electro-negative groups. The fact that an electric current splits compounds in solution into two portions led Berzelius to devise his "dualistic" system, which involved the assumption that all compounds consist of two portions, one electro-positive, the other electro-negative. Thus sulphate of magnesium and potassium was to be regarded as composed of electro-positive potassium sulphate in combination with electro-negative magnesium sulphate; the former in its turn consisted of electro-negative sulphur trioxide (SO_3) in combination with electro-positive oxide of potassium (K_2O); while each of these proximate constituents of potassium sulphate were themselves composed of the electro-negative oxygen in combination with electro-positive sulphur, or potassium. On contrasting sulphur with potassium, however, the former was considered more electro-negative than the latter; so that the group SO_3 as a whole was electro-negative, while K_2O was electro-positive. The symbols given above, which are still in universal use, were also devised by Berzelius for the purpose of illustrating and emphasizing his views. These views, however, met with little acceptance at the time in England.

Lavoisier's idea, that oxygen was the necessary constituent of all acids, began about this time to 52
lose ground. For Davy had proved the elementary nature of chlorine; and hydrochloric acid, one of the strongest, was thus seen to contain no oxygen, and Davy expressed the view, founded on his observation, that iodic "acid," I_2O_5, was devoid of acid properties until dissolved in water, and that the essential constituent of all acids was hydrogen, not oxygen. The bearing of this theory on the dualistic theory is, that while, *e.g.*, sulphuric acid was regarded by Berzelius as SO_3, containing no hydrogen, and was supposed to be separated as such at the positive pole of a battery, Davy's suggestion led to the opposite conclusion that the formula of sulphuric acid is H_2SO_4, and that by the current it is resolved into H_2 and SO_4. Faraday's electrolytic law, that when a current is passed through electrolytes in solution the elements are liberated in quantities proportional to their equivalents, led to the abandonment of the dualistic theory. For when a current is passed in succession through acidified water, fused lead chloride, and a solution of potassium sulphate, the quantities of hydrogen and oxygen from the water, of lead and chlorine from the lead chloride, and the potassium of the sulphate are in accordance with Faraday's law. But in addition to the potassium there is liberated at the same pole an equivalent of hydrogen. Now, if Berzelius's theory be true, the products should be SO_3 and K_2O, but if the opposite view be correct, then K_2 is liberated first and by its subsequent action on water it yields potash and its equivalent of hydrogen. This was pointed out first by Daniell, professor at King's College, London, and it was regarded as a powerful argument against Berzelius's system. In 1833, too, Graham investigated the phosphoric acids, and prepared the salts of three, to which he gave the names, *ortho*-, *pyro*-, and *meta*- phosphoric acids. To understand the bearing of this on the doctrine of dualism 53
it must be remembered that P_2O_5, pentoxide of phosphorus, was at that date named phosphoric acid. When dissolved in water it reacts with bases, forming salts—the phosphates. But the quantity of water necessary was not then considered essential; Graham, however, showed that there exist three series of salts—one set derived from $P_2O_5,3H_2O$, one from $P_2O_5,2H_2O$, and a third from P_2O_5,H_2O. His way of stating the fact was that water could play the part of a base; for example, the ordinary phosphate of commerce possessed, according to him, the formula $P_2O_5,2Na_2O,H_2O$, two-thirds of the "water of constitution" being replaced by oxide of sodium. Liebig, then professor at Giessen (1803–1873), founded on these and on similar observations of his own the doctrine of poly-basic acids—acids in

which one, two, three, or more atoms of hydrogen were replaceable by metals. Thus, instead of writing, as Graham did, $P_2O_5,2Na_2O,H_2O$, he wrote, PO_4Na_2H; and for orthophosphoric acid PO_4H_3. The group of atoms (PO_4), therefore, existed throughout the whole series of orthophosphates, and could exist in combination with hydrogen, with hydrogen and metals, or with metals alone. Similarly the group (P_2O_7) was characteristic of pyrophosphates and (PO_3) of metaphosphates, for $P_2O_5,2H_2O=(P_2O_7)H_4$; and $P_2O_5,H_2O=2(PO_3)H$.

The first clear ideas of the structure of the molecule were, however, gained from the study of the compounds of carbon. It was difficult to apply the dualistic theory to them. For few of them are electrolytes, and therefore their products of electrolysis, being non-existent, could not be classified. Nevertheless, Gay-Lussac regarded alcohol, C_2H_6O, as a compound of C_2H_4, ethylene, and H_2O, water; and oxalic acid (anhydrous), C_2O_3, as one of CO_2 with CO. The discovery of “isomeric compounds,” *i.e.*, of compounds which possess the same ultimate formula and yet differ entirely in their properties, forced upon chemists the necessity of attending to the structure of the molecule; for 54 only by such a supposition could the difference between two isomeric bodies be explained. In 1823 Liebig discovered that silver fulminate and silver cyanate both possessed the empirical formula AgCNO; in 1825 this was followed by the discovery by Faraday that oil gas contains a hydrocarbon identical in composition with ethylene, C_2H_4, yet differing from it in properties; and in 1829 Wöhler, professor in Göttingen (1800–1882), discovered that urea, a constituent of urine, could be produced by heating ammonium cyanate, NH_4CNO, a substance of the same formula. It therefore became clear that the identity of a compound must depend on some other cause than its ultimate composition.

In 1833 Liebig and Wöhler took an important step in elucidating this question by their investigations on benzoic acid and acid obtainable by distilling a resin named gum benzoin. They showed that this acid, $C_7H_6O_2$, could be conceived as consisting of the group C_7H_5O, to which they gave the name “benzoyl,” in combination with OH; that benzoic aldehyde, C_7H_6O, might be regarded as its compound with hydrogen; that it also formed compounds with chlorine, and bromine, and sulphur, and replaced hydrogen in ammonia (C_7H_6O,NH_2). They termed this group, benzoyl, a “compound element” or a “radical.” This research was followed by one by Robert Bunsen, professor at Heidelberg, born in 1811, and recently (1899) dead, which bore reference to cacodyl, a compound of arsenic, carbon and hydrogen, in which the idea of a radical was confirmed and amplified.

The idea of a radical having thus become established, Jean Baptiste Andrée Dumas, professor in Paris (1800–1884), propounded the theory of “substitution,” *i.e.*, that an element such as chlorine or oxygen (which, be it noticed, is electro-negative on Berzelius’s scale) could replace hydrogen in 55 carbon compounds, atom for atom, the resulting compound belonging to the same “type” as the one from which it was derived. And Laurent, warden of the mint at Paris (1807–1853), and Gerhardt, professor at Montpelier and at Strasburg (1816–1856), emphasized the fact that one element, be it what it may, can replace another without fundamentally altering its chemical character, and also that an atom of hydrogen can be replaced by a group of atoms or radical, behaving for the occasion like the atom of an element. It is to Laurent and Gerhardt that we owe the definition of an atom—*the smallest quantity of an element which can be present in a compound*; an equivalent—*that weight of an element which combines with or replaces one part by weight of hydrogen*; and a molecule—*the smallest quantity which can exist in a free state, whether of an element or a compound*. They recognized, too, that a molecule of hydrogen, chlorine, etc., consists of two atoms.

In 1849 Wurtz, professor in Paris (1817–1884), and Hofmann, then professor in the College of Chemistry in London, afterwards at Berlin (1818–1892), discovered a series of compounds allied to ammonia, NH_3, in which one or more atoms of hydrogen were replaced by a group or radical, such as methyl (CH_3), ethyl (C_2H_5), or phenyl (C_6H_5). Wurtz referred such compounds to the ammonia “type.” They all resemble ammonia in their physical properties—smell, taste, etc.—as well as in their power of uniting with acids to form salts resembling ammonium chloride (NH_4Cl), and other ammonium compounds. Shortly afterwards Williamson, professor at University College, London, added the “water type,” in consequence of his researches on “mixed ethers”—bodies in which the hydrogen of water might be regarded as replaced by organic radicals. Thus we have the series:

H. O. H.; CH_3. O. H.; CH_3. O. CH_3; and NH_3; NH_2; H_3; $NH(CH_3)_2$; and $N(CH_3)_3$; the first 56
representing compounds following the water type, the latter the ammonia type. This suggestion had been previously made by Laurent, in 1846. But Williamson extended his views to inorganic compounds; thus, sulphuric acid was represented as constructed on the double water type—HO. SO_2. OH, being derived from H. O. (H. H) O. H, the two hydrogen atoms enclosed in brackets being replaced by the radical SO_2. To these types Gerhardt added the hydrogen and hydrogen chloride types, H.H. and H.Cl; and, later, Kekulé, professor in Bonn (1829), added the marsh gas type $C(H)_4$. The next important step was taken by Frankland, professor in the Royal School of Mines, London; his work, however, had been anticipated by Cunn Brown, professor at Edinburgh University, in a pamphlet even yet little known. It was to attribute to elements one or more powers of combination. To these he gave the name "valency," and the capacity of possessing valency was called "quantivalence." Thus hydrogen was taken as a "monad," or monovalent. Chlorine, because it unites with hydrogen atom to atom, is also a monad. Oxygen, having the power to combine with two atoms of hydrogen, was termed a dyad, or divalent; nitrogen a triad, or trivalent; carbon a tetrad, or tetravalent, and so on. This is evident from inspection of the formulas of their compounds with hydrogen, thus:

```
                          H       H   H
                         /         \ /
H——Cl;  H——O——H;  H——N     ;      C
                         \         / \
                          H       H   H
```

Instances of penta, hexa, and even hepta-valency are not wanting.

This was the key to unlock the structure of chemical compounds; and Frankland's views, just stated, are still held by chemists. The determination of the constitution of compounds, chiefly those of
carbon, occupied the attention of chemists, almost exclusively, until 1880. The plan of action is much 57
the same as that of a mechanician who wishes to imitate a complicated mechanism. He must first dissect it into groups of mechanical contrivances; these are next constructed; and they are finally built together into the complete machine. In certain cases the atoms of carbon are arranged in "chains," as, for example, in pentyl alcohol:

```
H₃C——C——C——C——C——O——H
     H₂ H₂ H₂ H₂
```

each atom being tetrad, and its "affinities," or powers of combination, saturated either with hydrogen or with those of neighboring atoms of carbon; in others they are in the form of a "ring," as in benzene, the formula of which was first suggested by Kekulé, viz.:

```
    H   H
    C——C
   /    \
HC       CH;
   \    /
    C==C
    H   H
```

or in both, as in ethyl benzene,

```
    H   H
    C——C
   /    \    H   H
HC       C——C——CH.
   \    /    H   H
    C==C
    H   H
```

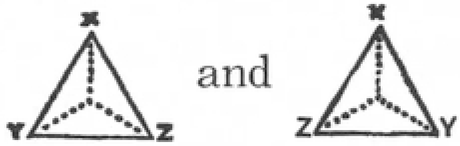
One or more atoms of nitrogen, or of oxygen, may form part of the circle, as in pyridine:

```
  H  H                                H  H
  C——C                                C  C
 /    \                              /
N      CH  and furfurane,           O  ==  ,
 \    /                              \
  C==C                                C  C
  H  H                                H  H
```

and so on. By means of conceptions such as these many interesting compounds have been built up out of the elements which they contain; *e.g.*, urea and uric acid, constituents of urine; theobromine and caffeine, the essential principles of cocoa and tea; alizarine and indigo, valuable dyestuffs; and several of the alkaloids, bitter principles contained in plants, of great medicinal value.

They have led, too, to the discovery of many brilliant colors, now almost universally employed, to 58
the exclusion of those less brilliant, because less pure, derived from plants, and in one or two cases from animals; the manufacture of gun-cotton, dynamite, and similar high explosives; and to the development of the candle industry; the sugar manufacture; to improvement in tanning, in brewing, and in the preparation of gas and oils for illuminating purposes. In short, it may be said that the industrial progress of the latter half of the century has been due to the theoretical views of which a short sketch has just been given.

Such formulas, however, can evidently not represent the true constitution of matter, inasmuch as the atoms are imagined to lie on a plane, whereas it is evident that they must occupy space of three dimensions and possess the attributes of solidity. The conception which led to the formulation of such views was due first to Pasteur, in his later years director of the institute known by his name at Paris, and more directly to LeBel and Van't Hoff, now professor at Berlin, independently of each other. In 1848 Pasteur discovered that it was possible to separate the two varieties of tartaric acid from each other; and that that one which rotated the plane of polarized light to the right gave crystals with an extra face, unsymmetrically disposed with regard to the other faces of the crystal. The variety, the solution of which in water was capable of producing left-handed rotation, also possessed a similar face, but so placed that its reflection in a mirror reproduced the right-handed variety. Pasteur also showed that a mixture of these acids gave crystals not characterized by an unsymmetrically placed face; and also that the solution was without action on polarized light. These observations remained
unexplained, until LeBel and Van't Hoff, in 1874, simultaneously and independently devised a theory 59
which has, up till now, stood the test of research. It is briefly this: Imagine two regular tetrahedra, or three-sided pyramids, standing each on its triangular base. An idea can best be got by a model, easily made by laying on a table three lucifer matches so as to form an equilateral triangle, and erecting a tripod with three other matches, so that each leg of the tripod stands on one corner of the triangle. At the centre of such a tetrahedron, an atom of carbon is supposed to be placed. Marsh gas, CH_4, is supposed to have such a structure, each corner, or solid angle of the structure (of which there are four), being occupied by an atom of hydrogen. This represents the solid or *stereochemical* formula of methane or marsh gas. Now, suppose one of the atoms of hydrogen in each of these structures to be replaced by chlorine, the group (OH), or any other monovalent element or group. It is evident that if not exactly similar (owing to the replacement not having been made at similar corners in each), the two structures can be made similar by turning one of them round, until the position of the substituting atom or group (which we will term X) coincides in position with X in the stationary one. If two such replacements be made, say, with X and Y in each, coincidence can again be made to take place; but the same is not the case if X, Y, and Z replace three atoms of hydrogen in the structure; for there is one way of replacement which is the optical image of the other, and represents the other's reflection in a mirror.



(Tetrahedron XYZ) and (Tetrahedron XZY)

Now, it is found that when the four corners of such a structure are occupied by four separate atoms or groups, or when (as the expression goes) the body contains an "asymmetrical carbon atom," if the 60 substance or one of its derivations can be obtained in a crystalline form, the crystals are also asymmetric, *i.e.*, arc develops a face which is the mirror-reflection of a similar face developed on the other variety; and if a beam of polarized light be passed through the solution of the substance, its plane is rotated to the left if one variety be used, and, if the other, to the right. This hypothesis of LeBel's and Van't Hoff's has had an enormous influence on the progress of organic chemistry. By its means Fischer, now professor at Berlin, has explained the reason of the existence of the enormous number of bodies analogous to grape and cane sugar, and has prepared many new varieties; and it appears likely that the terpenes, a class of bodies allied to turpentine, and comprising most of the substances to which the odor of flowers is due, may thereby find their explanation. It may be mentioned in passing that Pasteur, having found that ordinary mould destroyed one variety of tartaric acid rather than the other in a mixture of the two, and made use of this observation in order to prepare the unattached variety in a state of purity, was led to study the action of organisms more or less resembling mould; and that this has led to the development of the science of bacteriology, which has had an enormous influence on our views regarding fermentation in general, and guides the work of our physicians, our surgeons (witness Lister's antiseptic treatment), our sanitary engineers in their estimate of the purity of drinking-water and of the disposal of sewage, of our manufacturers of beer and spirits, of wine-growers, and more recently of farmers. All these processes depend upon the action of organisms in producing chemical changes, whether in the tissues of the body, causing or curing disease, or in the production of flavored alcohol from sugar, or in the manufacture of butter and cheese, or in preparing the land for the 61 reception of crops. We also owe to the genius of Van't Hoff the most important advance of recent times in the region of physical chemistry. It has been observed by Raoult, professor at Grenoble, that the freezing-point of a solvent as a general rule is lowered to the same extent if there be dissolved in it quantities of substances proportional to their molecular weights. Thus, supposing 1.80 grams of grape-sugar be dissolved in 100 grams of water and the solution cooled below 0° with constant stirring, ice separates suddenly in thin spicules, and the temperature rises to −0.185°. If 3.42 grams of cane-sugar be similarly dissolved in 100 grams of water, the freezing-point of the solution is again −0.185°. Now, 1.80 and 3.42 are respectively the hundredth part of the molecular weights of grape-sugar ($C_6H_{12}O_6$) and cane-sugar ($C_{12}H_{22}O_{11}$). Similarly, Raoult found that quantities proportional to molecular weights dissolved in a solvent depress the vapor pressure of that solvent equally, or, what comes to the same thing, raise its boiling-point by an equal number of degrees. But ordinary salts, such as sodium chloride, potassium nitrate, etc., dissolved in water, give too great a depression of the freezing-point and too high a boiling-point. Next, it has been observed by botanists, Devries, Pfeffer, and others, who had examined the ascent of sap in plants, that if a vessel of unglazed porcelain, so treated as to cause a film of cupric ferrocyanide (a slimy red compound) to deposit in the pores of its walls, be filled with a weak (about 1 per cent.) solution of sugar or similar substance, and plunged in a vessel of pure water, water entered through the pores. By attaching a monometer to the porous vessel the pressure exerted by the entering water could be measured. Such pressure was termed "osmotic pressure," referring to the "osmosis" or passage through the walls of the vessel. Such prepared walls are permeable freely to 62 water, but not to sugar or similar bodies. Van't Hoff pointed out that the total pressure registered is proportional to the amount of substance in solution, and that it is proportional to the absolute temperature, and he showed, besides, that the pressure exerted by the sugar molecules is the same as that which would be exerted at the same temperature were an equal number of molecules of hydrogen to occupy the same volume as the sugar solution. This may be expressed by stating that when in dilute solution sugar molecules behave *as if* they were present in the gaseous state. Here again, however, it was noticed that salts tended to give a higher pressure; it was difficult to construct a semi-permeable diaphragm, however, which would resist the passage of salt molecules, while allowing those of water to pass freely. Lastly, Arrhenius, of Stockholm, had shown that the conductivity of salt solutions for electricity may be explained on the assumption that when a salt, such as KNO_3 is dissolved in water, it dissociates into portions similar in number and kind to those it would yield if electrolyzed (and if no secondary reactions were to take place). Such portions (K and NO_3, for example) had been named ions by Faraday. The conductivity of such solutions becomes greater, per unit of dissolved salt, the weaker the solution, until finally a limit is reached, after which further dilution no longer increases conductivity. Now Van’t Hoff united all these isolated observations and showed their bearing on each other. Stated shortly, the hypothesis is as follows: When a substance is dissolved in a large quantity of a solvent, its molecules are separated from each other to a distance comparable with that which obtains in gases. They are, therefore, capable of independent action; and when placed in a vessel the walls of which are permeable to the solvent, but not to the dissolved substance (“semi-permeable membrane”), 63 the imprisoned molecules of the latter exert pressure on the interior surface of these walls as if they were gaseous. Van’t Hoff showed the intimate connection between this phenomenon and the depression of freezing-point and the use of vapor pressure already alluded to. He pointed out further that the exceptions to this behavior, noticed in the case of dissolved salts, are due to their “electric dissociation,” or “ionization,” as it is now termed; and that in a sufficiently dilute solution of potassium nitrate, for example, the osmotic pressure, and the correlated depression of freezing-point and rise of boiling-point, are practically equal to what would be produced were the salt to be split into its ions, K and NO_3. These views were vigorously advocated by Ostwald, professor at Leipzig, in his *Zeitschrift für physikalische Chemie*, and he and his pupils have done much to gather together facts in confirmation of this theory, and in extending its scope.

It must be understood that the ions K and NO_3 are not, strictly speaking, atoms; they are *charged* atoms; the K retains a +, and the NO_3 a − charge. On immersing into the solution the poles of a battery, one charged + and the other −, the + K atoms are attracted to the − pole, and are there discharged; as soon as they lose their charge they are free to act on the water, when they liberate their equivalent of hydrogen. Similarly, the − NO_3 groups are discharged at the + pole, and abstract hydrogen from the water, liberating an equivalent quantity of oxygen. Thus the phenomenon of electrolysis, so long a mysterious process, finds a simple explanation. The course of ordinary chemical reactions is also readily realized when viewed in the light of this theory. Take, for example, the ordinary equation:

$$AgNO_3.Aq + NaCl.Ag = AgCl + NaNO_3.Aq;$$

i.e., solutions of silver nitrate and sodium chloride give a precipitate of silver chloride, leaving sodium 64 nitrate in solution. By the new views, such an equation must be written:

$$\overset{+}{Ag}.Aq + \overset{-}{NO_3}.Aq + \overset{+}{Na}.Aq + \overset{-}{Cl}.Aq = AgCl + \overset{+}{Na}.Aq + \overset{-}{NO_3}.Aq.$$

The compound, silver chloride, being insoluble in water, is formed by the union of the ions Ag and Cl, and their consequent discharge, forming an electrically neutral compound; while the sodium ions, charged positively together with the NO_3 ions, negatively charged, remain in solution.

One more application of the principle may be given. Many observers—Andrews, Favre, and Silbermann, but especially Julius Thomsen, of Copenhagen, and M. Berthelot, of Paris—have devoted much labor and time to the measurement of the heat evolved during chemical reactions. Now, while very different amounts of heat are evolved when chlorine, bromine, or iodine combine respectively with sodium or potassium, the number of heat units evolved on neutralizing sodium or potassium hydroxide with hydrochloric, hydrobromic, hydriodic, or nitric acids is always about 13,500. How can this fact be explained? It finds its explanation as follows: These acids and bases are ionized in solution as shown in the equation:

$$\overset{+}{H}.Aq + \overset{-}{Cl}.Aq. + \overset{+}{Na}.Aq + \overset{-}{OH}.Aq = H.OH + \overset{+}{Na}.Aq + \overset{-}{Cl}.Aq.$$

Water is the only compound formed; and it is produced by the union of the hydrogen-ion originally belonging to the acid, and the OH or hydroxyl-ion originally belonging to the base. No further change has occurred; hence the uniform evolution of heat by the interaction of equivalent quantities of these acids and bases.

It now remains to give a short account of the greatest generalization which has as yet been made in chemistry. It has been termed the "Periodic Arrangement of the Elements." 65

In 1864 Newlands, of London, and Lothar Meyer, late of Tübingen, found that by arranging the elements in the order of their atomic weights certain regularities were to be observed between each element, and in general the eighth in succession from it, in the order of their numerical value. Such similar elements formed groups or quantities; while the elements separating them belong to a *period*, hence the name "periodic arrangement." Commencing with lithium, a light, lustrous metal found in silicate in certain minerals, we have the following series:

Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
7	9.2	11	12	14	16	19	20
Sodium	Magnesium	Aluminum	Silicon	Phosphorus	Sulphur	Chlorine	Argon
23	24.3	27	28	31	34	35.5	40

and so on. It is unnecessary to point out in detail the resemblances between the elements which stand in the vertical columns; but it may be stated that the resemblance extends also to the formulas and properties of their compounds. Thus the chlorides of lithium and sodium are each white soluble salts, of the formulas LiCl and NaCl; oxides of magnesium and of beryllium are both insoluble white earthy powders, MgO and BeO (GeO), and so on. Newlands, in his preliminary sketch, termed this order the "Law of Octaves," and predicted the existence of certain undiscovered elements which should occupy unfilled positions in the table. Mendeléef, professor at St. Petersburg, in 1869 amplified and extended these relations; and he and Meyer pointed out that the volume occupied by equal numbers of atoms of such elements underwent a periodic variation when the elements are classified as above. The 66 prediction of undiscovered elements was made by Mendeléef in a more assured manner; and in several cases they have been realized. Thus what Mendeléef called "ekaboron" has since been discovered by Lecoq de Boisbandron and named, patriotically, "gallium"; Mendeléef's "eka-silicon" is now known as "germanium," discovered by Winkler; and "eka-aluminum" is now Cléve's "scandium." Moreover, the atomic weights of cæsium, beryllium, molybdenium, and mercury have been altered so that they fit the periodic table; and further research has justified the alteration.

The valency of these elements increases from right to left, as will be seen by inspection of the following series:

LiCl	$BeCl_3$	BCl_3	CCl_4	NH_4Cl
Na_2O	MgO	B_2O_3	SiO_2	PCl_3
Monad.	Dyad.	Triad.	Tetrad.	Triad and Pentad.

OH_2	FH	Ne——
SO_3	$Cl(OH)O_3$	A——
Dyad and Hexad.	Monad and Heptad.	No valency.

The elements of no valency are of recent discovery. In 1894 Lord Rayleigh had determined the density of the nitrogen of the atmosphere, having separated from it the oxygen and carbon dioxide which is mixed with nitrogen in air. He found it to be of somewhat higher density than that obtainable from ammonia and other compounds of nitrogen. In conjunction with Ramsay he investigated atmospheric nitrogen; it was absorbed either by a method devised by Cavendish, or by making it combine with magnesium at a red heat. They found that the unabsorbable residue possessed an unknown spectrum, and that its density was nearly 20. To this new gas they gave the name "argon," or inactive, seeing that all attempts to cause it to enter into combination had failed. In 1895 Ramsay, 67 searching for possible combinations of argon in minerals, experimented with one which had been previously examined by Hillebrand, of Baltimore, and obtained from it helium, a gas of density 2, possessing a spectrum which had been previously discovered in 1868 in the chromosphere of the sun, by Jannsen, of Paris, and named helium by Frankland and Lockyer. Subsequent liquefaction of crude argon by means of liquid air, prepared by a process invented simultaneously by Linde and Hampson, gave a residue which was named by its discoverers, Ramsay and Travers, "neon." Liquid argon has yielded two other gases also, "krypon" and "xenon." These elements form a separate group in the Periodic Table, commencing with helium, with atomic weight, 4; neon, 20; argon, 40; krypon, 82; and xenon, 128. They all agree in being mono-atomic, *i.e.*, their molecules consist of single atoms; and they have no tendency to form compounds, *i.e.*, they possess no valency.

In this sketch of the progress of chemistry during the century which has just passed, attention has been paid chiefly to the progress of thought. Allusions must, however, be made to the applications of chemistry to industrial purposes. The development of the soda industry, the preparation of carbonate of soda and caustic from common salt—initiated in France by LeBlanc (1742–1806)—has been developed by Tennant, in Scotland, and Muspeath and Gossage, and by Hargreaves, Weldon, and Maetea, in England; this process has at present a serious rival in the ammonia-soda process, developed by Solway, in Belgium, and by Brunner and Mond, in England. The main action of sulphuric acid, so long associated with the alkali process, has made enormous strides during the present century, but is still, in the main, the original process of causing sulphur dioxide in presence of water to absorb the oxygen of the air through nitric oxide. But the saving of the oxides of nitrogen through the invention 68 of a sulphuric acid power by Gay-Lussac, known by his name, and the re-utilization of these oxides in the "Glover" power, invented by John Glover, of Newcastle, have greatly lessened the cost of the acid. Concentration of the acid in iron vessels is now common, the cost of platinum or of fragile glass vessels being thereby saved. The desulphurization of iron and the removal of silicon, carbon, and phosphorus by Bessemer's process, modified by Thomas and Gilchrist through the introduction of a "basic magnesia lining" for the convertors, has made it possible to obtain pure iron and steel from ores previously regarded as of little value.

The use of artificial manures, prepared by mixing refuse animal matters with tetra-hydrogen, calcium phosphate, and nitrate of soda, or sulphate of ammonia, first introduced by Liebig, has created a revolution in agricultural methods and in the weight of crops obtainable from a given area of soil. The influence of manures on crops has been fully studied by Lawes and Gilbert for more than fifty years in their experimental farm at Rothampstead. The most remarkable advances which have been made, however, are due to cheap electric current. The electrolysis of alumina, dissolved in fused cryolite to obtain aluminum, an operation carried out at Schaffhausen-on-the-Rhine, and at the Falls of Foyers, in Scotland; the electro-deposition of pure copper for electric wires and cables, electro-silvering, gilding, and nickelling, all these are instances where decomposition of a compound by the electric current has led to important industrial results. At present soda and chlorine are being manufactured by the electrolysis of salt solution contained in rocking trays, one of the electrodes being mercury, by the Castner-Kellner process. This manufacture is being carried on at Niagara, as well as in England. But electricity as a heating agent finds ever-extending application. Louis Moisson, professor 69 at Paris, led the way by utilizing the enormous heat of the ore in his electric furnace, thereby, among other interesting reactions, manufacturing diamonds, small, it is true, though none the less real. The use of electricity as a heating agent has received new applications. Phosphorus is now made by distilling a mixture of phosphates of lime and alumina with coke; a new polishing agent has been found in "carborundum," a compound of carbon and silicon, produced by heating in an electric furnace a mixture of sand and coke; and cyanide of potassium, almost indispensable for the extraction of gold from ores poor in gold, is now manufactured by heating a mixture of carbon and carbonate of barium in an electric furnace in a current of carbon monoxide. These are but some of the instances in which electricity has been adopted as an agent in effecting chemical changes; and it may be confidently predicted that the earlier years of the twentieth century will witness a great development in this direction. It may be pointed out that the later developments of industrial chemistry owe their success entirely to the growth of chemical theory; and it is obvious that that nation which possesses the most competent chemists, theoretical and practical, is destined to succeed in the competition with other nations for commercial supremacy and all its concomitant advantages.

William Ramsay.

ARCHÆOLOGY

To write of the progress of archæology in this century is scarcely possible, as the idea of the subject was unknown a hundred years ago; it is, therefore, the whole history of its opening and development that we have to deal with. The conception of the history of man being preserved to us in material facts, and not only in written words, was quite disregarded until the growth of geology had taught men to read nature for themselves, instead of trusting to the interpretations formed by their ancestors. Even down to the present the academic view is that classical archæology is more important than other branches, because it serves to illustrate classical literature. Looked at as archæology, it is, on the contrary, the least important branch, because we already know so much more of the classical ages than we do of others.

It is only within the present generation that it has been realized that wherever man has lived he has left the traces of his action, and that a systematic and observant study of those remains will interpret to us what his life was, what his abilities and tastes were, and the extent and nature of his mind. Literature is but one branch of the archæology of the higher races; another—equally important for the understanding of man—is art; these two give the highest and most complex and characteristic view of the nature of a race. At the opposite end of the scale are the rudest stone weapons which remain as the sole traces of the savages who used them. These highest and lowest evidences of mind, and all that lies [74] between them, are the domain of archæology.

We now purpose to review the growth of archæology in contact with geology, where it concerns man as the last of the links of life on the globe; and then to notice the archæology of each country in turn, as it leads on to the times of historical record, and so passes down to modern times.

A century ago the world of thought was divided between the old and new ideas very differently from what is now the case. Then there stood on one side the idea of a special creation of an individual man, at 4000 B. C.; the compression of all human history into a prehistoric age of about three thousand years, and a fairly logical solution of most of the difficulties of understanding in a comfortable teleology. On the other hand stood many who felt the inherent improbability of such solutions of the problem of life, and who were feeling their way to some more workable theory on the basis of Laplace, Lamarck, Erasmus Darwin, and others; vaguely mingling together questions of physics, geology, archæology, anthropology, and theology, each of which we now see must be treated on its own basis, and be decided on internal evidence, before we can venture to let it affect our judgment on other points.

The great new force which thrust itself in to divide and decide on these questions is the scientific study of man and his works. Strangely shaped flints had been noticed, but no one had any knowledge of their age. One such, when found with the bones of a mammoth, was attributed to the Roman age, because no person could have brought elephants into Britain except some Roman general. The argument was excellent and irrefutable until geology found plenty more remains of the mammoth and showed that it was here long before the Romans. It was less than half a century ago that our eyes [75] began to open to the abundant remains of flint-using man. Then a single rude stone weapon was an unexplained curiosity; now an active collector will put together his tens of thousands of specimens, will know exactly where they were found, their relation of age and of purpose, and their bearing on the history of man.

Not only have worked flint implements been found in the river gravels of France and England, where they were first noticed in the middle of this century, but also in most parts of Europe, in Egypt on the high desert, in Somaliland, at the Cape of Good Hope, in India, America, and other countries; and the most striking feature is the exact similarity in form wherever they have been found. So precisely do the same types recur, so impossible would it be to say from its form whether a flint had been found in Europe, Asia, or Africa, that it appears as if the art of working had spread from some single centre over the rest of the world. This is especially the case with the river-gravel flints—the earlier class—usually called Paleolithic. Soon after the general division had been made between polished stone-work of the later or Neolithic times, found on the surface, and the rough chipped work of the earlier or Paleolithic times, found in geological deposits, a further sub-division was made by separating the Paleolithic age into that of the river gravels and that of the cave-dwellers. The latter has again been divided into three classes by French writers, named, from their localities, *Mousterien*, *Solutrien*, *Magdalenien*; and, though these classes may be much influenced by locality, they probably have some difference of age between them.

And now within the last few years a still earlier kind of workmanship has been recognized in flints found in England on the high hills in Kent. Though at first much disputed, the human origin of the forms is now generally acknowledged, and they show a far ruder ability than even the most massive of 76
the Paleolithic forms. The position also of these flints, in river deposits lying on the highest hills some six hundred feet above the present rivers, shows that the whole of the valleys has been excavated since they were deposited, and implies a far greater age than any of the gravel beds of the Paleolithic ages.

We, therefore, have passed now at the beginning of this century to a far wider view of man's history, and classify his earlier ages in Europe thus:

First—Eolithic: Rudest massive flints from deposits 600 feet up.

Second—Paleolithic: Massive flints from gravels 200 feet up and less (Achuleen).

Third—Paleolithic—Cave-dwellers: Flints like the preceding and flakes (Mousterien).

Fourth—Paleolithic—Cave-dwellers: Flints well worked and finely shaped (Solutrien).

Fifth—Paleolithic—Cave-dwellers: Abundant bone working and drawing (Magdalenien).

Sixth—Neolithic: Polished flint working, pastoral and agricultural man.

What time these periods cover nothing yet proves. The date of 4000 B. C. for man's appearance, with which belief the nineteenth century started, has been pushed back by one discovery after another. Estimates of from 10,000 to 200,000 years have been given from various possible clews. In Egypt an exposure of 7000 years or more only gives a faint brown tint to flints lying side by side with Paleolithic flints that are black with age. I incline to think that 100,000 years B. C. for the rise of the second class, and 10,000 B. C. for the rise of the sixth class will be a moderate estimate.

Passing now from Paleolithic man of the latest geological times whose works lie under the deposit of ages, to Neolithic man of surface history whose polished stone tools lie on the ground, we find also how greatly views have changed. For ages past metal-using man has looked on the beautifully 77
polished or chipped weapons of his forefathers as "thunderbolts," possessing magic powers, and he often mounted the smaller ones to wear as charms. At the beginning of this century well-finished stone weapons were only preserved as curiosities which might belong to some remote age, but without any definite ideas about them. The recognition of long ages of earlier unpolished stone work has now put these more elaborate specimens to a comparatively late period, and yet they are probably older than the date to which our forefathers placed the creation of man.

The beginning of a more intelligent knowledge of such things was laid by the systematic excavations of the burial mounds scattered over the south of England, which was done in the early part of this century by Sir Richard Colt Hoare. A solid basis of facts was laid, which began to supersede the romances woven by Stukeley and others in the last century. Gradually more exact methods of search were introduced, and in the last thirty years Canon Greenwell has done much, and General Pitt Rivers has established a standard of accurate and complete work with perfect recording, which is the highest development of archæological study. These and other researches have opened up the life of Neolithic man to us, and we see that he was much as modern man, if compared with the earlier stage of man as a hunter. The Neolithic man made pottery, spun and wove linen, constructed enormous earthworks both for defence and for burial, and systematically made his tools of the best material he could obtain by combined labor in mining. The extensive flint-mines in chalk districts of England show long-continued labor; and the perfect form and splendid finish of many of the stone weapons show that skilled leisure could be devoted to them, and that æsthetic taste had been developed. The large camps prove that a thorough tribal organization prevailed, though probably confined to small clans. 78

About the middle of the century a new type of dwelling began to be explored—the lake dwelling; this system of building towns upon piles in lakes had the great advantage of protection from enemies and wild beasts, and a constant supply of food in the fish that could be hooked from the water below. Though such settlements were first found in the Swiss lakes, and explored there by Keller, they have since been found in France, Hungary, Italy, Holland, and the British Isles. The earlier settlements of this form belong to the Neolithic age, but only in central Europe. In these earliest lake dwellings weaving was known, and the cultivation of flax, grapes, and other fruit and corn; while the usual domestic animals were kept and cattle were yoked to the plough; pottery was abundant, and was often ornamented with geometric patterns. The type of man was round-headed. Following the Neolithic lake dwellings came those of the Bronze age, and as the bronze objects are similar to those found in other kinds of dwellings we shall notice them in the Bronze age in general. The type of man was longer-headed than in the earlier lake settlement. The domestication of animals shows an advance; the horse was common, and the dog, ox, pig, and sheep were greatly improved. Pottery was better made and elaborately decorated, often with strips of tin-foil.

The Bronze age marks a great step in man's history. In many countries the use of copper, hardened by arsenic or oxide, was common for long before the alloy of copper and tin was used. In other countries, where the use of metals was imported, copper only appears as a native imitation of the imported bronze. Hence there is a true age of copper in lands where the use of metals has grown. It must by no means be supposed that copper excluded the use of flint; it was not until bronze became common that flint was disused. The existence of a Bronze age was first formulated, as distinct from a 79
Stone age, about seventy years ago; and the existence of a Copper age has been much disputed in the last thirty years, but has only been proved clearly ten years ago, in Egypt.

In the eighteenth century the bronze weapons found in England were attributed to the Romans by some writers, though others, with more reason, argued that they were British. In the first year of the century began the comparative study of such weapons with reference to modern savage products. The development of the metal forms from stone prototypes was pointed out in 1816; the tracing out of the succession of the forms and the modes of use appeared in 1847. Further study cleared up the details, and within the last twenty years the full knowledge of the Bronze age in other countries has left no question as to the general facts of the sequence of its history. In each type of tool and weapon there appears first a very simple form imitated from the stone implements which were earlier used. Gradually the facilities given by the casting and toughness of the metal were used, and the forms were modified; ornamentation was added, and thin work in embossed patterns gave the stiffness and strength which had been attained before by massive forms. The general types are the axe—first a plain slip of metal, later developed with a socket; then the chisel, gouge, sickle, knife, dagger, sword, spear, and shield; personal objects, as pins, necklets, bracelets, ear-rings, buttons, buckles, and domestic caldrons and cups. Most of these forms were found together, all worn out and broken, in the great bronze-founder's hoard at Bologna.

Lastly in the prehistory of Europe comes the Iron age, which so much belongs to the historical period that we can best consider it in noticing separate countries.

From the recent discoveries in Egypt we can gain some idea of the date of these periods. We 80
ventured to assign about 10,000 B. C. for the rise of the Neolithic or polished-stone period (it may very possibly be earlier); the beginning of the use of copper may be placed about 5000 B. C.; the beginning of bronze was perhaps 3000 or 2000 B. C., as its free use in Egypt is not till 1600 B. C.; and the use of iron beginning about 1000 B. C., probably in Armenia, spreading thence through Europe until it reached Italy, perhaps 700 years B. C., and Britain about 400 B. C. Such is the briefest outline of the greater part of the history of man, massed together in one general term of "prehistoric," before we reach the little fringe of history nearest to our own age. The whole of this knowledge results from the work of the century.

We now turn to the historical ages of each of the principal countries, to review what advance has been made even where a basis of written record has come down to us, equally accessible in all recent times.

EGYPT

At the beginning of the century Egypt was a land of untouched and inexplicable mystery; the hieroglyphics were wondered at, and puzzled over, without any idea of how they were to be read, whether as symbols or as letters. The history was entirely derived from the confused accounts of Greek authors, the lists remaining of Manetho's history, written about 260 B. C., and the allusions in the Bible. The attempt to make everything fit to the ideas of the Greeks, and to make everything refer to the Biblical history, greatly retarded the understanding of the monuments, and is scarcely overcome yet. The first great step forward was when an inscription was found at Rosetta, in 1799, written in two methods, the monumental hieroglyphic and the popular demotic, along with a Greek version. By 1802 [81] some groups of each writing had been translated. Young identified more signs, and Gell, by 1822, could successfully apportion three-quarters of the signs to the Greek words. The next step was to apply the modern Coptic language, descended from the ancient Egyptian, to the reading of the words. Gell had been doing so, but it needed a student of Coptic—Champollion—to carry this out thoroughly, as he did in 1821–32. Since then advance in reading has been only a matter of detail, not requiring any new principles.

The knowledge of the art began with the admiration for the debased work of Roman times, the principal interest at the beginning of the century. Then the excavations among the Rameside monuments at Thebes, about 1820–30, took attention back to the age of 1500–1000 B. C. The work of Lepsius, and later of Mariette, from 1840–80, opened men's eyes to the splendid work of the early dynasties, about 4000–3000 B. C. And lastly the excavations of 1893–99 have fascinated scholars by a view of the rise of the civilization and the prehistoric period before 5000 B. C.

Throughout the greater part of the century the archæology of Egypt lay untouched; all attention was given to the language; and even Gardner Wilkinson's fine view of the civilization (1837) depended largely on Greek authors, and had no perspective of history in tracing changes and development. It is only in the last ten or fifteen years that any exact knowledge has been acquired about the rise and progress of the various arts of life; this study now enables us to date the sculpture, metal work, pottery, and other art products as exactly as we can those of the Middle Ages.

The view that we now have of the rise and decay of this great civilization and its connection with other lands is more complete and far-reaching than that of any other country. In the early undated age, before the monarchy which began about 4800 B. C., a flourishing civilization was spread over upper [82] Egypt. Towns were built of brick, as in later times; clothing was made of woven linen and of leather; pottery was most skilfully formed, without the potter's wheel, hand-made, yet of exquisite regularity and beauty of outline, while the variety of form is perhaps greater than in any other land; stone vases were made entirely by hand, without a lathe, as perfect in form as the pottery, and of the hardest rocks, as diorite and granite; wood was carved for furniture; the art of colored glazing was common, and was even applied to glazing over large carvings in rock crystal; ornaments and beads were wrought of various stones and precious metals; ivory combs with carved figures adorned the hair; ivory spoons were used at the table; finely formed weapons and tools of copper served where strength was needful, while more useful were flint knives and lances which were wrought with a miraculous finish that has never been reached by any other people; and games were played with dainty pieces made of hard stone and of ivory. But all this tasteful skill of 6000–5000 B. C. had its negative side; in the artistic copying of nature the mechanical skill of these people carried them a very little way; their figures and heads of men and animals are strangely crude. And they had no system of writing, although marks were commonly used. They always buried the body doubled up, and often preserved the head and hands separately. Commerce was already active, and large rowing-galleys carried the wares of different countries around the Mediterranean. These people were the same as the modern Kabyle, of Algeria, and akin to the South European races, but with some negro admixture. Our whole knowledge of this age has only been gained within the last five years.

At about 5000 B. C. there poured into Egypt a very different people, probably from the Red Sea. Having far more artistic taste, a commoner use of metals, a system of writing already begun, and a more organized government, these fresh people started a new civilization in Egypt; adopting readily the art and skill of the earlier race, they formed by their union the peculiar culture known as Egyptian, a type which lasted for four thousand years. The same foundation of a type is seen in the bodily structure; the early historical people had wider heads and more slender noses than the prehistoric, but from 4000 B. C. down to Roman times the form shows no change. 83

From this union of two able races came one of the finest peoples ever seen, the Egyptians of the old kingdom, 4500—3500 B. C. Full of grand conceptions, active, able, highly mechanical, and yet splendid artists, they have left behind them the greatest masses of building, the most accurate workmanship and exquisite sculptures in the grand pyramids and tombs of their cemeteries. They perfected the art of organizing combined labor on the immense public works. In all these respects no later age or country has advanced beyond this early ability. The moral character and ideas are preserved to us in the writings of these people; and we there read of the ability, reserve, steadfastness, and kindliness which we see reflected in the lifelike portraiture of that age.

After a partial decay about 3000 B. C. this civilization blossomed out again nobly in the twelfth dynasty about 2600 B. C.; though the works of this age hardly reach the high level of the earlier times, yet they are finer than anything that followed them. At this period more contact with other countries is seen; both Syria and the Mediterranean were known, though imperfectly.

To this succeeded another decadence, sealed by the disaster of the foreign invasion of the Hyksos. But this was thrown off by the rise of a third age of brilliance—the eighteenth dynasty, 1500 B. C.— 84 which, though inferior to early times in its highest work, yet shines by the widespread of art and luxury throughout the upper classes. Magnificence became fashionable, and the lower classes contented themselves with most barefaced imitations of costly wares. Foreign islands came closely in contact with Egypt. The ships of the Syrian coast and Cyprus continually traded to and fro, exchanging silver, copper, and precious stones for the gold of Egypt. Greece also traded its fine pottery of the Mycenæan age for the showy necklaces of gold and the rings and amulets with names of Pharaohs. Egypt then dominated the shores of the western Mediterranean, the plains of the Euphrates, and the fertile Soudan. But this power and wealth led to disaster. Like Rome, later on, she could not resist the temptation to live on plunder; heavy tribute of corn was exacted, large numbers were employed in unproductive labor, and national disaster was the natural consequence. Egypt never recovered the dominion or the splendor that were hers in this age. Of this period some slight notions are given us from literary remains in the Bible and Greek authors; but archæology is, so far, our only practical guide, as in the earlier ages. The great temples and monuments of the eighteenth-twentieth dynasties (1600–1100 B. C.) bear hundreds of historical inscriptions, the tombs are covered with scenes of private life, the burials and the ruins of towns furnish us with all the objects of daily use. This age is one of the fullest and richest in all history, and hardly any other is better known even in Greece or Italy. Yet all this has been brought to light in the century, and the knowledge of the foreign relations of Egypt is entirely the result of the last fifteen years.

The final thousand years of the civilization of Egypt is checkered with many changes; sometimes independent, as in the ages of Shishak of Necho, and of the Ptolemies; at other times a prey to 85 Ethiopians, Persians, Greeks, or Romans. Its arts and crafts show a constant decay, and there was but little left to resist the influence of Greek taste and design, which ran a debased course in the country. There was, however, a spread of manufactures and of cheap luxuries into lower and lower classes; and the wealth of the country accumulated under the beneficent rule of the earlier Ptolemies (300–200 B. C.).

The principal discoveries about these later ages have been in the papyri, which have been largely found during the last twenty years. The details of the government and life of the country in the Ptolemaic (305–30 B. C.) and Roman (30 B. C.–640 A. D.) periods have been cleared up; and many prizes of classical literature have also been recovered. The archæology of the Middle Ages in Egypt has also been studied. Many of the Arabic buildings have been recently cleaned and put in good condition, and the splendid collection of manuscripts in Cairo has opened a view of the beautiful art of the thirteenth-fifteenth centuries so closely akin to what was done in Europe at the same time.

Egypt is, then, before all other lands, the country of archæology. A continuous history of seven thousand years, with abundant remains of every period to illustrate it, and a rich prehistoric age before that, give completeness to the study and the fullest value to archæological research.

MESOPOTAMIA

The valley of the Euphrates might well rival that of the Nile if it were scientifically explored, but unhappily all the excavation has been done solely with a view to inscription and sculpture, and no proper record has been made, nor have any towns been examined, the only work being in palaces and 86 temples.

The earliest study on the ground was by Rich (1818–20), who gathered some few sculptures and formed an idea of Assyrian art. The French Consul, Botta, excavated Khorsabad (founded 700 B. C.) in 1834–35, and Layard excavated Nimrud in 1845–47; these were both Assyrian sites. The older Babylonian civilization was touched at Erech by Loftus, in 1849–52; and this age has attracted the most important excavations made since, at Tello by Sarzec (1876–81), and at Nippur by Peters and Haynes, of Philadelphia, during the last few years.

The cuneiform characters were absolutely unexplained until Grotefend, in 1800, resolved several of them by taking inscriptions which he presumed might contain names of Persian kings and comparing them alongside of the known names; thus—without a single fixed point to start from—he tried a series of hypotheses until he found one which fitted the facts. Bournouf (in 1836) and Lassen (1836–44) rectified and completed the alphabet. But the cuneiform signs were used to write many diverse languages, as the Roman alphabet is used at present; and the short Persian alphabet was only a fraction of the great syllabary of six hundred signs used for Assyrian. Rawlinson had independently made out the Persian alphabet, using the Zend and Sanskrit for the language. He next, from the trilingual Behistun inscription in Persian, Assyrian, and Vannic, resolved the long Assyrian syllabary, using Hebrew for the language. Since then other more obscure languages written in cuneiform have been worked with more or less success; the most important is the Turanian language, used by the earlier inhabitants of Babylonia before the Semitic invasion; this is recorded by many syllabaries and dictionaries, and translations compiled by the literary Semitic kings.

The general view of the civilization which has been obtained by these labors of the century shows 87
it to have been more important to the world than any other. Cuneiform was the literary script of the world for at least six thousand years, the only medium of writing from the Mediterranean to the Indian Ocean. The Babylonian culture was almost certainly the source of the oldest present civilization—that of China. And the arts were developed probably even earlier than in Egypt. The first inhabitants were called Sumirian (or river folk) in distinction from the Accadian (or highland) people, who came from Elam down into the Euphrates valley, bringing with them the use of writing. Their earliest writing was of figure symbols (like the Egyptian and Hittite); but as in the valley clay tablets were the only material for writing, the figures became gradually transformed into groups of straight lines and spots impressed on the clay; hence the signs were formalized into what we call cuneiform. The Semitic invaders were using cuneiform characters by about 3000 B. C.

The early civilization was intensely religious, the main buildings being the temples, which were placed on enormous piles of brick-work. The sculpture was at a high level in the time of Naram-Sinn, about 3750 B. C.; and yet below his ruins at Nippur there are no less than thirty-five feet depth of earlier ruins, which must extend back to 6000 or 7000 B. C. In early times stone implements were used alongside of copper and bronze, as we find in Egypt 4000 B. C. Pottery was well made, and also reliefs in terra-cotta. Personal ornaments of engraved gems and gold-work were common.

The main landmarks in the later time of this civilization are the Elamite invasion of Kudur-nan-khundi (2280 B. C.) which upset the Semitic rulers, and the Assyrian invasion of Tiglath-Adar (1270 B. C.), after which interest centres in the Assyrian kingdom and its development of the Mesopotamian 88 culture which it borrowed. The main buildings of the Assyrian kings were their enormous palaces, the mass of which was of unbaked bricks, faced with alabaster slabs; such were the works of Assurnazir-pal (Nimrud, 880 B. C.), Sargon (Khorsabad, 710 B. C.), Sennacherib and Assurbani-pal (Kouyunjik, 700 B. C.). The later, Assyrian, form of the civilization was to the earlier Chaldean much what Rome was to Greece, a rather clumsy borrower, who laboriously preserved the literature and art. Some of the Assyrian sculpture of animals is, however, perhaps unsurpassed for vivid action. The systematic libraries, containing copies of all the older literature for general study, were most creditable, though the Assyrian himself composed nothing better than chronicles. Nearly all that we possess of Babylonian religion, and much of the history, is in the copies scrupulously made from the ancient tablets by the Assyrian scribes, who noted every defect in the original with critical fidelity.

The Mesopotamian civilization has left its mark on the modern world. Its religion greatly influenced Hebrew, and thence Christian, thought, the psalms, for instance, being a Babylonian form of piety. Its science fixed the signs of the zodiac, the months of the year, the days of the week, and the division of the circle in degrees, all of which are now universal. And its art, carried by the Phœnicians, was copied by the Greeks and Etruscans, and thus passed on into modern design.

SYRIA

The knowledge of Palestine was but slight, and of northern Syria nothing to speak of, a century ago. Travellers with some scientific ability, such as Robinson (1838 and 1852), De Saulcy (1853), and Van de Velde (1854), greatly extended our view and led up to the splendid survey by the Palestine 89 Exploration Fund (1866 and on), which exhausted the surface study of the land. The more archæological work of excavation was begun at Jerusalem (1867–70), and resumed (1892–99) at Lachish, Jerusalem, etc. The topographical results are all important, and leave nothing to be done until excavation can be freely applied; and the small amount of digging yet done has fixed the varieties of pottery back to 2000 B. C. and given some early architecture. But the ruins of Syria, and indeed of Turkey in general, are practically yet untouched. The discovery (1868) of the inscription of Mesha, King of Moab (896 B. C.), opened a new prospect of research which cannot yet be entered upon. In the north of Syria nothing has been done except the German work at Singerli, from which came an Aramean inscription of about 740 B. C. And in the south a large number of early inscriptions of the Arabian dynasties, reaching back some centuries B. C., have been copied; but there, also, excavation is impossible.

The main new light from Syria has been on the Hittite power. Burckhardt, in 1812, had noticed a new kind of hieroglyph at Hamath. After several ineffective copies, Wright made casts of the stones in 1872. Several other such inscriptions have been found, and from these and the Egyptian and Assyrian references to the Hittites we now realize that they were a northern people, with a great capital on the Euphrates, at Karkhemish, and ruling over nearly all Syria and Asia Minor. Little has yet been fixed about the writing; a few signs are read and some have passed into the Cypriote alphabet. A striking proof of the spread of Babylonian culture is seen in the tablets found in Egypt at Tel-el-Amarna in 1887, which show that all the correspondence between Egypt and Syria in the fifteenth century B. C. was carried on in cuneiform. These hundreds of letters give a vivid picture of life in Syria at that early 90 date.

GREECE

The revival of interest in Greek civilization was at first purely literary, and remained so during two or three centuries. But during the last century various travellers and residents abroad made collections which awoke an interest in the art; and though most of these collectors were content with merely showy sculpture, greatly restored and falsified for the market, yet some—such as Hamilton—took a real archæological interest in the unearthing and collecting of ancient art. The condition of study at the end of the eighteenth century was that many private men of wealth had bought large quantities of sculpture which was but little understood, and looked on more from a decorative than a scientific point of view, while there were the beginnings of a serious appreciation of it which had been just laid down by Winckelmann.

The nineteenth century opened with a grand work of publishing the principal treasures of classical art in England, which was finally issued in 1809 by Payne, Knight, and Townley; this marks the highest point of the dilettante collecting spirit, which was soon eclipsed by truer knowledge. Hitherto the best sculpture had hardly been known but at second hand through Roman copies; a closer acquaintance began with the travels of Dodwell, Gell, and Leake, all in the first decade of the century. The free opening of the British Museum, in 1805, and the accumulation there of all the best collections within the first quarter of the century, also served to educate a public taste. The first struggle of scientific and artistic knowledge against the dilettante spirit was over the Elgin marbles; by 1816 they were accepted as the masterpieces which all later criticism has proved them to be. The Æginetan and [91] Phigaleian sculptures, brought to Munich and London, helped also to show the nobility of early Greek art; so that the last two generations have had a canon of taste to rely upon, the value of which cannot be overestimated.

Following on this noble foundation, other collectors worked in Greece and Asia Minor, and the British Museum profited by the labors of Burgon, Fellows, and Woodhouse between 1840 and 1860. The diplomatically supported work of Newton on the Mausoleum (1857–58), and Wood at Ephesus (1863–75), filled out our knowledge of the middle period of Greek art (350 B. C.). Comparatively little has been done since then by England, but the activity of the Germans at Olympia has given us the only original masterpiece that is known—the Hermes of Praxiteles (350 B. C.), and their work at Pergamon revealed the great altar belonging to the later age (180 B. C.). The excavations at Athens (in 1886) have produced the impressive statues dedicated to Athene about 520 B. C., which reveal the noble rise of Attic sculpture. But attention during the last quarter-century has been largely fixed upon the earlier ages. The discoveries of Schliemann at Hissarlik (Troy, 1870–82), Mycenæ (1876), Orchomenos (1880–81), and Tiryns (1884), opened a new world of thought and research. Though at first bitterly attacked, it is now agreed that these discoveries show us the civilization of Greece between 2000 and 1000 B. C. Lastly, during ten years past Egypt has provided the solid chronology for prehistoric Greece by discoveries of trade between the two countries.

We can now very briefly estimate the present position of our knowledge as gained during the century. Setting aside the early foreign pottery found in Egypt, which belongs probably to Greece or Italy at 5000 and 3000 B. C., we first touch a civilized city in the lowest town of Troy, where metal was scarcely yet in use, which is certainly before 2000 and probably about 3000 B. C. in date. Succeeding [92] that is the finely built second Troy, rich in gold vases and ornaments, which—though mistaken by Schliemann for the Homeric Troy—must yet be long before that, probably before 2000 B. C. After the burning of that come three other rebuildings before we reach the town of the age of Mycenæ, about 1500 B. C. Of this, which was in Greece the climax of the prehistoric civilization, there are the splendid treasures found at Mycenæ, the magnificent domed tombs, the abundance of fine jewelry and metal-work, of beautiful pottery and glazed ornament. To this age belong the great palaces of Mycenæ, Tiryns, Athens, and other hill fortresses, of which hardly more than the plans can now be traced. And it is this civilization which traded eagerly with Egypt, exchanging the valued manufactures of each country. This period was at its full bloom from 1500–1200 B. C., and began to decay by 1100 B. C., this dating being given by the contact with Egypt.

This natural decadence of art in Greece was hastened by the invasion of the barbarous Dorians about 1000 B. C. Art, however, was by no means extinguished, but only repressed by the troubles of the age; and Athens, which was not conquered by the Dorians, was the main centre of the revival of the

arts. Other examples of such a history are familiar in Egypt (after the Hyksos invasion) and in Italy (after the Lombards), where earlier abilities revive and bloom afresh when vigorous invaders become united to an artistic stock. After the centuries of warfare a quieter age allowed the growth of fine arts again in the seventh century B. C., largely influenced by Egyptian and Assyrian work at second hand, through the Greek settlements in Cyprus and Egypt. By 600 B. C. definite types of sculpture were started, and a course was begun which only ended in the fall of classical civilization. The century before the Persian invasion, in 480 B. C., was one of rapid development; and in sculpture and vase- 93
painting we see that this century carried forward the arts to technical perfection and the highest power of expression. Immediately after the Persian wars came the supreme works of Pheidias and Myron, most familiar in the Parthenon and the Discobolus; and in vase-painting comes the reversal from vases drawn in black on a red ground to the blocking out of the ground in black, leaving the figure in red, thus giving far greater scope to the filling in of finely drawn detail. The civilization of Athens was also at its height in this age, under Pericles, and the minor arts received their most refined and perfect treatment. After this comes nothing but ripening to decay. It must always be remembered that we have but very few examples of original work of the great artists. Nearly all the actual marbles preserved are copies made in later times, which show little of the delicacy of the original; and the few original marbles that remain are mostly of unknown subjects by unknown men. The great work in Greek archæology during the last fifty years has been comparing the records of ancient art (in Pliny, Pausanias, etc.) with the remaining sculptures, critically assigning the various types of statues to their celebrated originals, and thus forming some idea of the real history of Greek art.

From these studies, full of detail and controversy, we may briefly sum up the characteristics of the principal artists and their imitators. At about 440 B. C. Pheidias showed in the Parthenon the highest expression of divine and mythic forms, in a simple and heroic style which was never equalled. Half a century later Polykleitos followed a more human expression, using motives (as in the Doryphoros), but yet portraying an abstract humanity. By 330 B. C. Praxiteles brought the expression of moods to his works, graceful, animated, and with a full ripeness, as in the Hermes of Olympia, or the Faun. Skopas, 94
slightly later, marked his work by his great vigor and strong personality. This was the second turning-point, when ripeness passed into decay; and in Lysippos there is mere vivid naturalism and an impressionist manner without much soul or thought, as in his Apoxyomenos, about 330 B. C. After this mere triviality and genre subjects are usual, portraiture is a common aim, and dignity was vainly striven for in colossal size. The glorification of showing dead and vanquished enemies is seen in the Dying Gaul and figures of slain foes at Pergamon. Later on, about 180 B. C., we see the violent, complicated, and straining action of the figures around the great altar of Pergamon, which also appears in the groups of the Laocoon and Farnese Bull. In the Græco-Roman age a conscious artificiality took the place of life and expression, as we see in the Apollo Belvidere, the Venus di Medici, and the Farnese Hercules. Art was saved in the first century A. D. by the devotion of portraiture, which gave a sense of reality and conviction which is entirely absent in the imaginative works. Lastly, a painstaking study and admiration of earlier works led, under the wealthy patronage of Hadrian (130 A. D.), to an eclectic revival which was wholly artificial, and passed away within a generation. We have fixed on sculpture as the most complete expression of Greek art; in other directions there is neither enough material nor enough research to give us a connected view. Not a single town, hardly a single house, in Greece has been excavated; there is no consecutive knowledge of the ordinary products and objects of life; and there is very little recorded of the discoveries of the tombs. The artistic interest of the sculpture and architecture has starved other branches of archæology, and for Greece more remains to be done than for some less celebrated lands.

95

ITALY

The interest in Italy at the beginning of the nineteenth century was mainly for the sake of its second-hand version of Greek art, and for the architecture and painting of the Renaissance. On the contrary, now the objects from Greece itself have far eclipsed the Italian copies, and the interest lies in the early Italian civilization and its purely Roman derivatives; while modern taste values the mediæval

art of Italy far from the bastard products of the florid age which followed. The first detailed studies in Italy were those on Pompeii, especially by Gell (1817), which made that debased style very popular, and paved the way for appreciation of better work. The various isolated discoveries of Etruscan tombs were summed up in the admirable work of Dennis (1848), which presented a general view of that civilization which has not been superseded. The earlier Italic culture has been examined in many places where accidental discoveries have revealed it during the latter half of the nineteenth century, and especially in the systematic work of Zannoni, at Bologna (1870–75), and of Orsi, lately, in Sicily. The history of the city of Rome has been almost rewritten in the last thirty years owing to the great changes of the new government; these have been largely worked by Lanciani, and recorded by him and Middleton. The view of Italian history at present begins in the Stone age, which has been well studied, and has links with the later periods, as in the general use of black pottery. The earliest metal objects are very simple blades of daggers, found in graves, mingled with flint arrow-heads and knives. The admirable Italian plan of preserving whole burials undisturbed in museums enables us to see these graves complete in the Kircherian Museum. A special branch of the early Bronze age life was the system of lake dwellings (natural or artificially water girt), which abound in the northern Italian lakes 96
and over the plain of Lombardy. These towns (“terra mare”) are arranged on a rectangular plan, and form the earliest stage of many of the present cities. The full development of the Bronze age civilization seems to have been later than in Greece, at about 800 B. C., to which belong the great discoveries of tombs, weapons, and tools at Bologna, and the cemetery of Falerii.

Upon all the native Italic civilization came an entirely different influence from the immigrant Etruscan. Traditionally coming from Asia Minor, he brought art and religion which had no relation to the Italic. The earliest Etruscan paintings are strongly northern in style, influenced by north European feeling (Veii). But soon the Etruscan borrowed largely from other races, from the Greek mainly, but also from Assyria and Egypt. Thus the fascinating problem in Italy is to distinguish the various sources of Italic, Etruscan, Græco-Etruscan, Oriental-Etruscan, and pure Greek, which are found in all degrees of combination before Roman times, and which can still be traced through the Roman age. The characteristics of Etruscan taste are: (1) The extraneous objects and figures, such as rows of pendants to a metal vase, monstrous heads standing out from a bowl, and statuettes placed for handles; (2) in forms of vases and furniture, the combination of many different parts and curves which never form a whole design; (3) and in sculpture the large round head and staring eyes. In general, an air of clumsy adaptation by a race deficient in originality. The glory of the Etruscan was his engineering, which he handed as a legacy to Rome. Strange to say, although thousands of Etruscan inscriptions are known, and many words are translated, yet the language is sealed to us, and none of the many attempts to read it has succeeded. The scientific study of Etruscan tombs has been well followed lately, as shown in the 97
Florence Museum, where a separate room is devoted to each city.

In the south of Italy Greek art prevailed, and many of the finest works belong to this civilization. The Greek in Italy had rather different ideals to those of Greece; he started more from the level of Polykleitos and Praxiteles than from the severe age; his favorite type is that of youth and adolescence, never of maturity. The grace and feeling of such bronze statues as the Hermes and so-called Sappho of Herculaneum are peculiar to southern Italy. And when the Greek artist penetrated north and allied himself with the mechanical skill of the Etruscan, such splendid work was done as the Orator of Sanguineto.

Rome in the earlier centuries was an Italic town which came under Etruscan influence as Tuscany was conquered. But from the age of foreign conquest in the first century B. C., Greek art in a debased form ruled over all else, and ran into utter degradation in the third century A. D. It was this art that the power of Rome spread around the whole Mediterranean, from Palmyra to Britain, and is the parent of most modern decoration. But in the great reconstruction of the empire under Diocletian the debased Greek taste was mostly shaken off, and Rome went back to the old Italic-Etruscan style and motives. The statues have the round heads and staring eyes of old Etruria; the taste for quaint accessories, such as lions supporting objects, came back and passed into mediæval art, and the exaggerated, lengthy forms of men and animals reappeared.

Of the Christian period De Rossi's work in the catacombs has given a firm base of facts for the third to the sixth century A. D., the actual tomb and body of Saint Cecilia being the most striking result. The later Roman and mediæval age in Italy is full of interest, but in that—as in the rest of mediæval Europe—research has been mainly on architecture and objects which are not the result of excavation. [98]

INDIA

The Hindus have never been chronologists or historians, and their great Sanskrit literature tells practically nothing about the rise of Buddhism, the invasion of Alexander, or the spread of civilization in Indo-China. All before the Islamic conquest in the tenth century A. D. is in a mist of Puranic mythology. Here, then, more than in other countries, archæology has restored the history, and done so entirely within the nineteenth century.

The existence of Sanskrit literature was revealed to the West by Sir William Jones at the end of the last century, and this gave scope to Oriental scholars, while antiquities only interested the collector. But serious exploration was led by Prinsep, whose decipherment of the Asoka inscriptions in 1837, which ranks with the achievements of Champollion and Rawlinson, gave the key to a mass of inscriptions.

His assistant, Cunningham, excavated many sites and collected coins, being head of the Archæological Survey from 1861 to 1885. Fergusson was the historian of Indian architecture; Burgess has published the cave-temples in west and south India; Sewell in Madras and Führer in the northwest have excavated and explored, and a few native pundits have been educated to such research. The government, in financial difficulty, has withdrawn from the work, but the congress of Orientalists in 1897 resolved to establish an Indian exploration fund.

Inscriptions abound in India, on copper plate, stone pillars, and native rock. Those in Sanskrit, or modern vernaculars, are records of land grants or local dynasties. The oldest—in two different alphabets (of Semitic origin)—are the famous edicts of Asoka (third century B. C.), who has been [99] called The Buddhist Constantine. He placed these monuments of his power and religion around his frontiers of northern India; but their meaning was forgotten until Prinsep's decipherment. The Hindus seem to have a coinage of stamped silver plate before Alexander; but regular coinage begins in the Bactrian kingdoms (200 B. C.–200 A. D.), with Greek and native inscriptions. Since then the coinage is continuous, and invaluable for history. No stone building or sculpture is older than Alexander (327 B. C.), or certainly earlier than Asoka (264–233 B. C.). Greek influence is plain in the Punjab, but native style is seen in the cave-temples. The richest results have been from the mounds, some of which are ruins of forts or palaces, but the more important are the *stupas*, lofty domes erected two to one thousand years ago to enshrine Buddhist relics. These domes are surrounded with sculptured reliefs of scenes in the life of Buddha, and are often dated by inscriptions. From one lately opened the Buddha relic has been sent to the King of Siam, the only Buddhist king. Much has been done by the government in publishing and providing casts and photographs; but India yet needs a scientific archæologist to record details with the accuracy demanded by modern research.

AMERICA

Archæological work in the United States and in Central America was begun by Squier about the middle of the century, and the attention thus drawn to the subject has borne fruit in the more accurate and scientific explorations connected with the surveying and geological departments, and, above all, those of the Smithsonian Bureau of Ethnology. The names of Whitney, Wright, Cyrus Thomas, Holmes, Fowke, Mindeleff, and others, will be familiar to all American readers by their work of the [100] last twenty years, and need no introducing here.

The earliest remains of man in America—or perhaps in the world—are those beneath the great lava beds of California; since those were deposited the rivers have cut their beds through two thousand to four thousand feet of lava rock, implying an erosion during tens, or perhaps hundreds, of thousands of years. But little can be assigned, however, with any certainty to a date before the Christian era, though mounds of refuse on both ocean shores may probably belong to an age before any human history.

The most important studies have been those on the highest civilization of the continent, that of Central America. The destroying Spaniards preserved but little of native record, except incidentally, and the first collector of Aztec manuscripts was Benaduci (1736), of whose treasures but an eighth survived his imprisonments and persecutions, one of the greatest disasters to history. The first great publication of manuscripts was the magnificent work of Lord Kingsborough (1830); and almost at the same time appeared Prescott's history. Though the later researches have shown that the land was divided into many small kingdoms, rather than under one power, as Prescott supposed, yet his account of the calendar and chronology of the Aztecs has been verified and added to, and far more has been done in reading the manuscripts than he supposed possible. Aubin, after years of work in Mexico, brought to Europe manuscripts of an entirely new kind, showing a fully developed system of phonetic writing, which he has largely deciphered with success, having analyzed over one hundred syllabic values correctly.

One of the most complete studies has been that of the Mayan Quiché peoples, and especially of the Mayans of Yucatan. In 1864 Landa's work on Yucatan (written 1566) was rediscovered, and the 101
account of the calendar has sufficed to enable Goodman to discover the meaning of a very large number of signs (1897); these enable the numerical documents to be translated, and show that a period of as much as eight thousand years was dealt with by the Mayans, perhaps belonging to mythical ages. The alphabetic signs of Landa have proved useless so far, and Goodman even disbelieves in any record except that of numbers. Seler has shown the identical origin of the signs used by Aztecs and Mayans for the days and months. Little had been done to make known these remains until the recent explorations, casts, and publications of Maudsley, who has worked magnificently for seventeen years at Copan, Palenque, and Chichen-Itza; these, however, are but three of innumerable cities of Guatemala and Yucatan that need exploration.

In New Mexico the many ruins from the Colorado to the Rio Grande have been proved to resemble those of the modern Pueblo Indians, and to have none of the characteristics of Central American architecture; there are no sculptures, and the rock inscriptions are too primitive to be interpreted. Nothing points to an Aztec occupation, and probably the ancestors of the present people were the builders.

The innumerable earthworks of the Mississippi valley were formerly supposed to belong to some vanished race. And the view that they were connected with the Central American civilization is favored by the pyramid mound, which was hardly known otherwise, and by the excellence of the minor sculpture. But there are great differences between the two civilizations. The mound-builders were far inferior in metal-working, and their burial customs are peculiar. The use of materials from both east and west coasts shows an extensive commerce. The best summing up of the researches is that 102
by Prof. Cyrus Thomas, after his extensive excavations. He concludes that the remains of the mound-builders show no great antiquity; that they were formed by tribes like the existing Indians; that the builders were of the same culture as were the Indians when discovered; that such mounds continued to be made and used for burial during the European period, and that the principal builders were the Cherokees.

It will be seen now how totally our view of man's history has been changed by the study of archæology, and how fundamentally this science affects our ideas of the past and our expectations for the future of our race. The main outlines have been dimly seen; but in every country the greater part yet remains to be done, and in Turkey, Persia, and China most important civilizations are as yet quite untouched by exploration. The new century will no doubt see a harvest from these lands; and it is to be hoped that what yet remains in the safe keeping of the earth may be found by able men, who will preserve it for instruction and enable posterity to trace the fortunes of our species.

[India and America are here treated with the assistance of Mr. J. S. Cotton and Mr. D. MacIver.]

W. M. Flinders Petrie.

105

ASTRONOMY

In looking back over a century's work in the oldest of the sciences, one is struck not only by the enormous advance that has been made in those branches of the science dealing with the motions of the heavenly bodies which were cultivated at least eight thousand years ago by early dwellers in the valleys of the Nile, Tigris, and Euphrates, but with the fact that during the century that has just passed away a perfectly new science of astronomy arose. By annexing physics and chemistry astronomers now study the motions of the particles of which all celestial bodies are composed; a new molecular astronomy has now been firmly established side by side with the old molar astronomy which formerly alone occupied the thoughts of star-gazers.

Along this new line our knowledge has advanced by leaps and bounds, and the results already obtained in expanding and perfecting man's views of nature in all her beauty and immensity are second to none which have been garnered during the last hundred years.

THE POSITION AT THE BEGINNING OF THE CENTURY

It may be well before attempting to obtain a glimpse of recent progress that we should try to grasp the state of the science at the time when the nineteenth century was about to dawn, and this, perhaps, can be best accomplished by seeing what men were working at this period, at which the greatest activity was to be found in Germany; there was no permanent observatory in the southern hemisphere 106 or in the United States.

First and foremost among the workers—he has, in fact, been described as "the greatest of modern astronomers"—was William Herschel, a German domiciled in England. In the year 1773 he hired a telescope, and with this small instrument he obtained his first glimpses of the rich fields of exploration open in the skies. From that time onward he had one fixed purpose in his mind, which was to obtain as intimate knowledge as possible of the construction of the heavens.

To do this, of course, great optical power was necessary, and such was his energy that, as large instruments were not to be obtained at any price, he set to work and made them himself.

Herschel presented the beginning of the nineteenth century not only with a definite idea of the constitution of the stellar system, based on a connected body of facts and deductions from facts, as gleaned through his telescopes, but observations without number in many fields. He discovered a new planet, Uranus, and several satellites of the planets; published catalogues of nebulæ; established the gravitational bond between many "double stars," and carried on observations of the sun, then supposed to be a habitable globe. What Herschel did for observational astronomy and deductions therefrom, Laplace did for the furtherance of our knowledge concerning the exact motions of the bodies comprising the solar system. Newton had long before announced that gravitation was universal, and Laplace brought together investigations undertaken to determine the validity of this law. These were given to the world in his wonderful book on *Celestial Mechanics*, the first volumes of which appeared in 1799.

A survey of the work of these two great astronomers gives one an idea of what was going on in observational and mathematical astronomy at the beginning of the century. 107

The study was now destined to make rapid strides, as not only were new optical instruments—some designed for special purposes—introduced, new mathematical processes applied, fresh fields for research opened up, but the number of workers was considerably augmented by the increased means available; so much so, indeed, that the first astronomical periodical was founded by Von Zach in 1800 to facilitate intercommunications between the observers.

The first evening of the nineteenth century (January 1, 1801) augured well for progress. It had long been thought that all the members of the solar system had not as yet been discovered, and there was a very notable gap between the planets Mars and Jupiter, indicated by Bode's law. Observers were organized to make a thorough search for the missing planet, portions of the sky being divided between them for minute examination. It fell to the Italian observer, Piazzi, to discover a small body which was moving in an orbit between these two planets on the date named. The century thus began with a sensation, and because the new body, which was named "Ceres," was not of sufficient size to be accepted as the "missing planet," the idea was suggested that perhaps it was a fragment of a larger planet that had been blown to pieces in the past.

An opportunity here arose for mathematical astronomy to come to the help of the observer, for Ceres soon was lost in the solar rays, and in order to rediscover it, after it had passed conjunction, an approximate knowledge of its path and future position was necessary.

With the then existing methods of computation of orbits it was imperative to have numerous measured positions to use as data for the calculation. The scanty data available in the case of Ceres 108 were not sufficient for the application of the method. The occasion discovered a man, one of the greatest mathematicians of the nineteenth century, Karl Frederick Gauss, who, although only twenty-five years of age, undertook the solution of the problem by employing a system which he had devised, known as "the method of least squares," which enabled him to obtain a most probable result from a given set of observations.

This, with a more general method of orbit computation, also elaborated by himself, was sufficient to enable him to calculate future positions of Ceres, and on the anniversary of the original discovery, Olbers, another great pioneer in orbit calculations, found the planet in very nearly the position assigned by Gauss. So great was the curiosity regarding the other portions of the planet, which was supposed to have been shattered, that numerous observers at once commenced to search after other fragments.

These were the *actualities* of 1801 and thereabouts; but the seed of much future work was sown. Kant and Laplace had already occupied themselves with theories as to the world formation, and spectrum analysis as applied to the heavenly bodies may be said to have been started by Wollaston's observations of dark lines in the solar spectrum in 1802. Fraunhofer was then a boy at school. In the same year the first photographic prints were produced by Wedgewood and Davy.

OBSERVATORIES

It has been stated that at the beginning of the century there were no permanent observatories either in the southern hemisphere or in the United States. The end of the century finds us with two hundred observatories all told, of which fourteen are south of the equator and forty-seven in the United States, 109 among which latter are the best-equipped and most active in the world.

The observatory of Parramatta was the first established (1821) in the southern hemisphere. This was followed by that at the Cape of Good Hope in 1829. Of the more modern southern observatories from which the best work has come we may mention Cordova, the seat of Gould's important investigations, established in 1868, and Arequipa, a dependency of Harvard, whence the spectra of the southern stars have been secured, erected still more recently (1881).

I believe, but I do not know, that the large number of American observatories have radiated from Cincinnati, where, in consequence of eloquent appeals, both by voice and pen, from Mitchell, then professor of astronomy, an observatory was commenced in 1845. There can be no doubt that at the present moment, with the numerous well-equipped and active observatories, and the careful and thorough teaching established side by side with them, which enables numberless students to use the various instruments, the United States, in matters astronomical, fills the position occupied by Germany at the beginning of the century.

In Europe special observatories have been established at Meudon, Kensington, and Potsdam, so that new astrophysical inquiries may be undertaken without interfering with the prosecution or extension of the important meridional work carried on at Paris, Greenwich, and Berlin. A large proportion of the observations made by the Lick and Yerkes observatories in the United States has been astrophysical.

One of the special inquiries committed to the charge of the Solar Physics Observatory at Kensington at its establishment by the British government had relation to the possibility of running home meteorological changes on the earth, especially those followed by drought and famines in 110 various parts of the empire, to the varying changes in the sun indicated by the ebb and flow of spots on its surface. With this end in view observations of the sun were commenced in India and the Mauritius to supplement those taken at Greenwich. At the same time other daily observations of sun spots by a different method were commenced at Kensington.

This kind of work was at first considered ideally useless; we shall see later on what has become of it.

IMPROVEMENTS IN TELESCOPES

The progress in astronomical science throughout the nineteenth century has naturally to a great extent depended upon the advances made both in the optics of the telescope and the way in which they are mounted, either with circles to record exact times and positions, or made to move so as to keep a star or other celestial objects in the field of view while under observation. The perfection of definition and the magnitude of the lenses employed in the modern instrument have been responsible for many important discoveries.

Ever since the telescope was invented—Galileo's lens was smaller than those used in spectacles—men's minds have been concentrated on producing instruments of larger and larger size to fathom the cosmos to its innermost depths.

At the beginning of the century we were, as we have seen already, in possession of reflectors of large dimensions; Herschel's four-foot mirror, the instrument he was using in 1801, which had a focal length of forty feet, was capable of being employed with high magnifying powers; and it was the judicious use of these, on occasions when the finest of weather prevailed, that enabled him to enrich so extensively our knowledge of the stellar and planetary systems. For the ordinary work of astronomy, 111 however, especially when circles are used, refractors are the more suitable instruments. This form suffers less from the vicissitudes of weather and temperature, and is, therefore, more suited where exact measurements are required.

Towards the end of the eighteenth century a Swiss artisan, Pierre Guinard, after many years of patient labor, succeeded in producing pure disks of flint glass as large as six inches in diameter. The modern refracting telescope thus became possible.

In 1804 there was started at Munich the famous optical and mechanical institute, which soon made its presence felt in the astronomical world. Reforms in instrument making were soon taken in hand, and under the leadership of the great German astronomer, Bessel, great strides were made in instruments of precision. Fraunhofer, who had been silently working away at the theory of lenses, and making various experiments in the manufacture of glass, was joined, in 1805, by Guinard. In 1809 Troughton invented a new method of graduating circles, according to Airy the greatest improvement ever achieved in the art of instrument making.

In 1824 Fraunhofer successfully completed and perfected an object-glass of 9.9 inches in diameter for the Dorpat Observatory. This objective might literally have been called a "giant," for nothing approaching it in size had been previously made.

England, which was at one time the exclusive seat of the manufacture of refracting telescopes, was now completely outstripped by both Germany and France, and for this we had to thank "the short-sighted policy of the government, which had placed an exorbitant duty on the manufacture of flint glass." In 1833 the Dorpat refractor was eclipsed by one of fifteen inches aperture made for the Pulkowa Observatory by Merz & Mähler, Fraunhofer's successors, who about ten years later supplied 112 a similar instrument to Harvard College. At that time Lord Rosse emulated with success the efforts of Herschel and rehabilitated the reflector by producing a metallic mirror of six-foot aperture and fifty-four-foot focal length which he mounted at Parsonstown. The speculum weighed no less than four tons. To mount this immense mass efficiently and safely was a work of no light nature, but he successfully accomplished it, and eventually both mirror and the telescope, which weighed now altogether fourteen tons, were so well counterpoised that they could be easily moved in a limited direction by means of a windlass worked by two men. The perfection of the "seeing" qualities of this instrument and its enormous light-grasping powers were particularly striking, and observational astronomy was considerably enriched by the discoveries made with it.

Speculum metal was not destined to stay; ten years later (1857) the genius of Léon Foucault introduced glass mirrors with a thin coating of silver deposited chemically, and these have now universally superseded the metallic ones.

The long supremacy of Germany in the matter of refractors was broken down ultimately by the famous English optician and engineer, Thomas Cooke, of York. His first considerable instrument, one of seven inches aperture, was finished in 1851; and in 1865, a year before his lamented death, he completed the first of our present giant refractors, one of twenty-five inches aperture, for Mr. Newall, of Gateshead. In consequence of the success of Cooke's achievement other large refractors were soon undertaken.

Alvan Clarke, the famous optician of Cambridgeport, Massachusetts, at once commenced a twenty-six-inch for the Washington Observatory. The next was one of twenty-seven inches, made by Grubb for the Vienna Observatory. Object-glasses now grew inch by inch in size, depending on the 113 increased dimensions of disks that could be satisfactorily cast. Gautier, of Paris, completed a twenty-nine-and-a-half-inch for the Nice Observatory, while Alvan Clarke made an objective of thirty inches for Pulkowa. In 1877 the latter successfully completed the mounting of an objective of thirty-six inches for the Lick Observatory, but this immense lens was only achieved after a great number of failures. Even this large object-glass was surpassed in size by the completion in 1892 of the forty-inch which he made for the Yerkes Observatory, and by that made by Gautier for the Paris Exhibition of 1900.

So much, then, for the largest refractors. In recent years, since the introduction of the silver on glass mirrors, with their stability of figure and brilliant surface, which can be easily renewed, reflectors of large apertures are again being produced. The first of these was one of thirty-six inches aperture made by Calver for Dr. Common, who demonstrated its fine qualities and his own skill by the beautiful photographs of the nebula of Orion he was enabled to secure with it. Dr. Common himself has since turned his attention to the making and silvering of large mirrors of this kind, and the largest he has actually completed and mounted equatorially is one with a diameter of five feet. Another of thirty-six inches aperture is in use at the Solar Physics Observatory at Kensington.

The progress of depositing silver on glass has led of late years to important developments in which *plane* mirrors are used. Foucault was the first to utilize such mirrors in his "siderostat," in which such a mirror is made to move in front of a horizontal fixed telescope, which may be of any focal length, and no expensive dome or rising floor is required. The plane mirror of the siderostat in the Paris Exhibition telescope is six feet in diameter.

A variation of this instrument is the cœlostat more recently advocated by Lippmann. The Coudé 114 equatorial mounting also depends upon the use of plane mirrors; with such a telescope the observer is at rest at a fixed eye-piece or camera in a room which may be kept at any temperature.

Now that in astronomical work eye observations are indispensably supplemented by the employment of photography, an important modification of the refracting telescope has become necessary; this was first suggested by Rutherfurd.

The ordinary achromatic object-glass consists, as a rule, of two lenses, one made of flint and the other of crown glass; but in this form the photographic rays are not brought to the same focus as the visual rays. This, however, can be achieved by employing three lenses instead of two, each of different kinds of glass. The most modern improvement in the telescope is due to Mr. Dennis Taylor, of Cooke & Sons, and to Dr. Schott and Professor Abbe, whose researches in the manufacture of old and new varieties of optical glass have rendered Mr. Taylor's results feasible. By the Taylor lens outstanding color is abolished, all the rays being brought absolutely to the same focus; such lenses can therefore be used either for visual observations or for photography for spectroscopy.

SPECTROSCOPIC ASTRONOMY

The branch of physics which at the present day has assumed such mighty and far-reaching proportions in astronomical work is that dealing with spectrum analysis, which, although suggested as early as the time of Kepler, did not receive any impetus as regards its application to celestial bodies until the beginning of the present century at the hands of Wollaston and Fraunhofer. Then, however, it [115] still lacked the chemical touch supplied afterwards by Kirchhoff and Bunsen. They showed us that the spectrum observed when the light from any heated body is passed through a prism is an index to the chemical composition of the light source; the constitution of a vapor when in a condition to absorb light can be determined by an extension of the same principle, first demonstrated by Stokes, Angström, and Balfour Stewart, when the century was about half completed.

The first celestial body towards which the spectroscope was turned was our central luminary, the sun.

Wollaston first discovered that its spectrum was crossed by a few dark lines; we learned next from Fraunhofer, who in 1814 worked with instruments of greater power, that the solar spectrum was crossed not only by a few dark lines, but by some hundreds. Not content with examining the light of the sun, Fraunhofer turned his instrument towards the stars, the light of which he also examined, so that he may be justly called the inventor of stellar spectrum analysis. It is not to the credit of modern science that from this time forward spectrum analysis did not become a recognized branch of scientific inquiry, but, as a matter of fact, Fraunhofer's observations were buried in oblivion for nearly half a century. The importance of them was not recognized till the origin of the dark lines, both in sun and stars, had been explained by Stokes and others, as before stated. The lines in the solar spectrum were mapped with great diligence by Kirchhoff in 1861 and 1862, and later by Angström and Thalen, and this was done side by side with chemical work in the laboratory. The chemistry of the sun was thus to a great extent revealed; it was no longer a habitable globe, but one with its visible boundary at a fierce heat, surrounded by an atmosphere of metallic vapors, chief among them iron, also in a state of incandescence. To these metallic vapors Angström added hydrogen shortly afterwards. [116]

Here, then, was established a firm link between the heavens and the earth; the first step to the problem of the chemistry of space had been taken.

It was only natural that as advances were made the instrumental equipment should keep pace with them. Spectroscopes were built on a larger scale; more prisms, which meant greater dispersion, were employed to render the measurements of the lines in spectra more accurate. The growth of our knowledge especially necessitated the making of maps of the lines in the solar spectrum, and in the spectra of the chemical elements which had been compared with it on a natural scale. This was done by Angström, who utilized for this purpose the diffraction grating invented by Fraunhofer, and defined the position of all lines in spectra by their "wave lengths," in ten-millionths of a millimetre or "tenth-metres."

In 1862 Rutherfurd extended Fraunhofer's work on the stars by a first attempt at classification. Two years later Huggins and Miller produced maps of the spectra of some stars. Donati demonstrated that comets gave radiation spectra, and Huggins did the same for nebulæ.

By these observations comets and nebulæ were shown to be spectroscopically different from stars, which at that time were studied by their dark lines only.

Chiefly by the labors of Pickering, the energetic head of the Harvard Observatory, science has been enriched during the later years by observations of thousands of stellar spectra, the study of which has brought about the most marvellous advance in our knowledge.

These priceless data have enabled us now to classify the stars not only by their brightness, or their color, but by their chemistry.

Next to be chronicled is the application of the so-called Doppler-Fizeau principle, which teaches us that when a light source is approaching or receding from us the light waves are crushed together or 117
drawn out, so that the wave length is changed. The amount of change gives us the velocity of approach or recess, so that the rate of movement of stars towards or from the earth, or the up-rush or down-rush of the solar vapors on the sun's disk can be accurately determined. A further utilization of this principle is found when the stars are so close together that they appear as one if the plane of motion passes near the earth. A line common to the spectra of both stars will appear double twice in each revolution, when the motion to or from the earth, or, as it is termed, "in the line of sight," is greatest. "Spectroscopic doubles," as these stars are called, yield up many of their secrets which otherwise would elude us. Their time of revolution, the size of the orbit, and the combined mass can be determined.

To return from the stars to the sun.

By the device of throwing an image of the sun on the slit of the spectroscope the spectra of solar spots have been studied from 1866 onward, and a little later the brighter portions of the sun's outer envelopes, revealed till then only during eclipses, were brought within our ken spectroscopically, so that they are now studied every day.

CELESTIAL PHOTOGRAPHY

Wedgewood and Davy, in 1802, made prints on paper by means of silver salts, but it was not until 1830 that Niepce and Daguerre founded photography, which Arago, in an address to the French Chamber, at once suggested might subsequently be used to record the positions of stars.

In 1839 we find Sir John Herschel carrying out a series of experiments so important for our correct knowledge of the sequence of steps in the early stages of photography that I have no hesitation in quoting from one of Herschel's manuscripts relating to a deposit on a glass plate of "muriate" 118
[chloride] of silver from a mixed solution of the nitrate with common salt. The manuscript states: "After forty-eight hours [the chloride] had formed a film firm enough to bear draining the water off very slowly by a siphon. Having dried it, I found that it was very little affected by light, and by washing it with nitrate of silver, weak, and drying it, it became highly sensitive. In this state I took a camera picture of the telescope on it."

The original of the above-mentioned photograph, the first photograph ever taken on glass, is now in the science collection at the Victoria and Albert Museum, South Kensington.

In the early days of photography colored glasses were first used to investigate the action of different colors on the photographic plate. Sir John Herschel was among the first to propose that such investigations should be made direct with a spectrum, and he, like Dr. J. W. Draper, stated that he had found a new kind of light beyond the blue end of the spectrum, as the photographic plate showed a portion of the spectrum there which was not visible to the eye. Advance followed advance, and in 1842 Becquerel photographed the whole solar spectrum, in colors, with nearly all the lines registered by the hand and eye of Fraunhofer, not only the blue end, but the complete spectrum, from Draper's "latent light," as he called the ultra-violet rays, to the extreme red end.

The first photograph of a celestial object was one of the moon, secured by Dr. J. W. Draper in 1840; we had to wait till 1845, so far as I know, before a daguerreotype was taken of the sun; this was done by Foucault and Fizeau, while the first photograph of a star—Vega—was taken at Harvard in 1850. After the introduction of the wet-collodion process regular photography of the sun's surface was 119
commenced, at Sir John Herschel's recommendation, at Kew in 1858, and the total solar eclipse of 1860 was made memorable by the photographs of De La Rue, who before that time had secured most admirable photographs of the moon, as also had Rutherfurd.

Photography now began to pay the debt she owed to spectrum analysis.

The first laboratory photograph of the spectra of the chemical elements was taken by Dr. W. A. Miller in 1862.

Rutherfurd was the first to secure a photograph of the solar spectrum with considerable dispersion by means of prisms.

In 1863 Mascart undertook a complete photographic investigation of the ultra-violet portion of the solar spectrum, a work of no mean magnitude. He, however, did not employ a train of prisms for producing the spectrum, but a diffraction grating, using the light reflected from the first surface. The first photograph of the spectrum of a star was secured by Henry Draper, the son of Dr. J. W. Draper, one of the pioneers in photography in 1872.

It was not till the introduction of dry plates in 1876 that the photography of the fainter celestial objects or of their spectra was possible, as a long exposure was naturally required. Stellar spectra were photographed by Huggins in 1879, and in the next year Draper photographed the nebula of Orion. As the dry plates became more rapid, and as longer exposures were employed, revelation followed revelation; the nebulæ as seen by the naked eye, and even some stars, were found by the Henrys, Roberts, Max Wolf, Barnard, and others, to be but the brighter kernels of large nebulous patches.

This new application of photography, depending upon long exposures (the longest one I know of has extended to forty hours), had an important reflex action on the mechanical parts of the telescope; it 120
was not only necessary to keep the faintest star exactly on the same part of the plate during the whole of the exposure, but night after night the stellar image must be brought on to the same part of the plate so that the exposure might be continued.

A system of electric control of the going of the driving-clock of the telescope by means of a sidereal clock was introduced, the simplest one being designed by Russell, of Sydney; a most elaborate one by Grubb, of Dublin.

Another application of the method of long exposures has been the discovery of minor planets by the trails impressed by their motion among the stars on the photographic plates on which the images of both are impressed.

A complete spectroscopic survey of the stars by means of photography was commenced in 1886 at Harvard College, as a memorial to Draper, who died while he was laboring diligently and successfully in securing advances in astrophysical inquiries. To carry on this work at Harvard, Professor Pickering wisely reverted to the method first employed by Fraunhofer, and utilized by Respighi and another in 1871, of placing prisms in front of the object-glass.

In the photographing of stellar spectra by means of objective prisms, the driving-clock of the telescope must *not* go exactly at sidereal rate, but at certain speeds depending on the brightness and position of the star under examination.

This is necessary because the image of the spectrum of a star on the photograph is only a thin line in which it is impossible to see the spectral lines; the spectrum must be broadened, and this is accomplished by making the star image "trail" to a certain degree on the plate. This trailing is accomplished by means of the clock, the rate of which is made to vary. In this way the trail of a 121
spectrum of a star on the photographic plate is always obtained of the same width, while the density of the image is made fairly constant by increasing the rate for bright stars and decreasing it for fainter ones. In this way spectra of the brighter stars rivalling in perfection and detail those obtained of the

spectrum of the sun itself thirty years ago have been obtained. Such photographs have rendered a minute chemical classification of the stars possible.

One of the most interesting applications of photography to spectrum analysis during the latter part of the century has been the utilization by Messrs. Deslandres and Hale of a suggestion made by Janssen, that by employing photography images of the sun and its surroundings can be obtained in light on one wave length. In this way we can study the distribution of any one of the chemical constituents of the sun separately, and note its behavior, not only on the sun itself, but in the atmosphere which enfolds the disk.

It is strange that, in spite of the suggestions of Faye, and others after him, one of the great advantages of the employment of photography in astronomical work, namely, the abolition of "personal equation," has so far been almost entirely neglected. What "personal equation" is can be perhaps illustrated by considering an observer who is observing the transit of a star over the wires in a transit instrument.

His object is to note the exact time, to a fraction of a second, when a star passes each wire; and this is done by listening to the beats of a clock near at hand and estimating the fractions. Some observers constantly note the time either a little in advance or a little later than the actual time, and this small distance between the observer and the true times is more or less constant for each observer. This difference has to be taken into account for every observation. Even the use of the chronograph in 122 transit work, by which the observation is electrically recorded, does not entirely eliminate the error. The photographic method of transit work has been experimented on, but, so far as I know, it has not yet been used at more than one or two observatories. It will doubtless eventually rid us of "personal equation" entirely, for the star image may be photographed and the time recorded by the same current of electricity.

At the end of the century we could almost say that except in relation to the work of the meridional observatories, photographic methods of recording observations had become exclusively used. One of the cases in which its utility is most in evidence is in the matter of eclipse observations. Spectra of the sun's surroundings containing a thousand lines are taken in a second of time, thus replacing five or six doubtful eye observations by wealth of results which have enabled the recent vast progress to be secured.

CATALOGUES

Catalogues of the stars were among the first scientific records started by man, and so long as only the naked eye was used the work was not difficult, as only approximate positions were attempted, even by Hipparchus; but long before the eighteenth century dawned the problem was entirely changed by the invention of the telescope and by the provision of accurately divided circles; not only could better positions be recorded, but the number of stars to be catalogued was enormously increased, and, furthermore, other objects, nebulæ, presented themselves in considerable numbers.

In 1801 the star catalogues chiefly relied on were those of Lacaille, containing about three thousand stars scattered over the whole heavens.

Maskelyne, who was then Astronomer Royal, had published in 1790 a catalogue of thirty-six 123 fundamental stars, chiefly for the purposes of navigation. The first great catalogue of the century was the *Fundamenta Astronomiae* of Bessel, produced in 1818. This contained three thousand two hundred and twenty-two stars. The Bonn *Durchmüsterung*, with its catalogue of three hundred and twenty-four thousand one hundred and ninety-eight stars in the northern hemisphere, and the corresponding atlas published in 1857–63, was the next memorable achievement in this direction. For it we have to thank Bessel and Argelander and a perfect system of work.

Another monumental catalogue dealing with the stars in the southern heavens has been that of the southern stars observed by Gould (1866). While the century was closing, another catalogue, far more stupendous than anything which could be conceived possible a few years ago, was steadily being compiled. This we owe to the far-sightedness and energy of Admiral Mouchez, a late director of the Paris Observatory. The work was commenced in 1892.

The whole heavens, north and south alike, have been divided into zones, and the chief observatories on the earth's surface are busy night after night in taking photographs of that part intrusted to them. The whole heavens are thus being made to write their autobiography, and the total gain to the astronomy of the future of this most priceless record can perhaps be scarcely grasped as yet, although the advantage of being able at any point of future time to see on a photographic plate what the heavens are telling now is sufficiently obvious.

Catalogues of the stars have, of course, led to other minor catalogues of various classes of stars, binary, variable, and the like. In the later years catalogues of stars according to their spectra have enriched science.

The first extensive catalogue of stellar spectra was published by Vogel. It dealt with four thousand 124
and fifty-one stars, and appeared in 1883; it has since been followed by the Draper catalogue, based upon photographs of the spectra, which contains a much larger number. With regard to nebulæ, Herschel published his third catalogue in 1802. The last catalogue of this nature is by Dreyer (1888), and contains seven thousand eight hundred and forty of these objects. In the time of Tycho they could be counted on the fingers of one hand.

INVESTIGATIONS OF SOME IMPORTANT ASTRONOMICAL CONSTANTS

The nineteenth century was fruitful in the determination of many numerical values which are all important in enabling us to determine the distance and masses of the heavenly bodies, thereby giving us a firm grasp not only of the dimensions of our own system, but of those scattered in the celestial spaces.

To take the distances first. We must begin with the exact measure of the earth; for this we must measure the exact length of an arc of meridian or of parallel—that is, a stretch of the earth's surface lying north and south or east and west, between places of which the latitudes are accurately known in the former case, and the longitude in the latter. In either case we can determine the number of miles which go to a degree. Beginning at the opening of the nineteenth century with an arc of meridian of two degrees measured by Gauss, from Göttingen to Altona, the arcs of meridian grew longer as the century grew older, till, at the close, the measurement of an arc of meridian from the Cape to Cairo, embracing something like sixty-eight degrees of latitude, was mooted.

The measurements of arcs of parallel have been developed by the rapid extension of telegraphic 125
communications, which now permit the longitude of the terminal stations to be determined with the greatest accuracy.

Thanks to this work, we now have the size of our planet to a few miles. The polar diameter is 41,709,790 feet, but the equator is not a circle: the equatorial diameter from longitude 8 degrees 15 minutes west to longitude 188 degrees 15 minutes west is 41,853,258 feet; that at right angles to it is 41,850,210 feet—that is, some thousand yards shorter. The earth, then, is shaped like an orange slightly squeezed.

Knowing the earth's diameter, we can obtain the sun's distance by several methods, the old one by observing transits of Venus, one of which Cook went out to observe in 1768, and two of which recurred in 1874 and 1882; new ones by observations of Mars or one of the minor planets at a favorable opposition, and by determining the velocity of light.

The recent discovery of a minor planet, Eros, which in one part of its orbit is nearer the earth than Mars, has recently revived interest in this method, and a combined attack is in contemplation.

It has been long known that light has a finite velocity, but we had to wait till the 60's before Fizeau and Foucault showed us how to determine its exact value. The methods introduced by them have been recently applied by Cornu, Newcomb, and Michelson, and the resulting value is slightly less than three hundred thousand metres per second. Combining this with the constant of aberration, the distance of the sun can be determined.

It is wonderful how these vastly different methods agree in the resulting mean distance. At the beginning of the century it stood roughly at ninety-five million miles; this has been reduced to ninety-three million nine hundred and sixty-five thousand miles. The extreme difference between the old and 126 new values of the solar parallax, two-fifths of a second of arc, is represented by the apparent breadth of a human hair viewed at a distance of about one hundred and twenty-five feet.

Knowing the distance of the sun, the way is open to us to determine, by a method suggested by Galileo, the distances of those stars which occupy a different position among their fellows, as seen from opposite points in the earth's orbit round the sun, points one hundred and eighty-six million miles apart. We now know the distances of many such stars, Bessel having determined the first in 1838. The nearest star to us, so far as we know, is Centauri, the light of which takes four and a half years to reach us. Not many years ago Pritchard applied photography to this branch of inquiry; we may, therefore, expect a still more rapid progress in the future.

With regard to masses. We naturally must first know that of the earth; having its size, if we can determine its density, the rest follows.

The problem of determining the mean density of the earth occupied the minds of many workers during the nineteenth century. Newton (about 1728) pointed out how it could be deduced by observing the deviation from the vertical of a plumb-line suspended near a large mass of matter—a mountain, the volume and density of which could be previously determined. This method, which is very laborious and requires the greatest skill and most delicate instruments, has been employed several times, by Bouguer and Condamine, in 1738, at Chimborazo; Maskelyne, in 1774, at Schehallien in Scotland; and James, at Arthur's Seat, near Edinburgh.

At the beginning of the century another method was introduced by Cavendish. This consists in measuring the attraction of two large spheres of known size and mass, such as two balls of lead on two very small and light spheres, by means of a torsion balance constructed by Mitchell for this purpose. 127

The most recent determination by this method, and one which is considered to give us perhaps the most accurate value, is that which is due to the skill and ingenuity of Professor Boys. His improvement consisted in constructing a most delicate torsion balance; the attracted spheres consisted of small gold balls suspended by a quartz fibre carrying a mirror to indicate the amount of twist. The whole instrument was quite small, and could easily be protected from air currents and changes of temperature, while the use of the quartz fibres reduced to a minimum one of the greatest difficulties of the Cavendish experiment. The value of the mean density of the earth is now considered to be 5.6, which means that if we have a globe of water exactly the same size as our own earth, the real earth would weigh just 5.6 times this globe of water. The earth's weight, in tons, does not convey much idea, but that it is six thousand trillions may interest the curious. This determination has enabled the masses of the sun, moon, planets and satellites, and many sidereal systems to be accurately known in relation to the mass of the earth.

SOME ACHIEVEMENTS OF MATHEMATICAL ANALYSIS

Uranus, a planet unknown to the ancients, was discovered by its movement among the stars by William Herschel in 1781. It was not until 1846 that another major planet was added to the solar system, and this discovery was one of the sensations of the century.

The story of the independent discovery of Neptune by Adams and Le Verrier, who were both driven to the conclusion that certain apparent regularities in the motion of Uranus were due to the attraction of another body travelling on an orbit outside it, has been often told. The subsequent discovery of the external body not far from the place at which their mathematical analysis had led them to believe it would be seen, will forever be regarded as a fine triumph of the human intellect. 128

But the results of the inquiries which now concern us are generally of not so sensational a character, although they lie at the root of our knowledge of celestial motions. They more often take the shape of tables and discussions relating to the movements of the bodies which make up our solar system.

Gauss may be said to have led the way during the nineteenth century by his *Theoria molus corporum coelestium solem ambientium*. This was a worthy sequel to the *Méchanique Céleste*, in which work, towards the end of the eighteenth century, Laplace had enshrined all that was known on the planetary results of gravitation.

In later years Le Verrier and Newcomb have been among the chief workers on whom the mantle of such distinguished predecessors has fallen. From them the planet and satellite tables now in use have been derived.

But the motion of our own satellite, the moon, has had fascinations for other analysts besides those we have named.

The problem, indeed, of the moon's motion is one of the most difficult, and has taxed the ingenuity of astronomers from an early date. Even at the present day it is impossible to predict the exact position of the moon at any one moment owing to inequalities and perturbations, the exact varying values of which are not known.

The two most important theories of the motion of the moon completed towards the middle of the century were due to Hansen and Delaunay. The former's appeared in 1838, the lunar tables being published later (1857), while the latter's was published in 1860.

Hansen's theory had for its chief object the formation of tables; to avoid the inconvenience of 129 using in his calculations series which slowly converge, he inserted numerical values throughout. In Hansen's solution the problem is one actually presented by nature, allowance being made for every known cause of disturbance. There is one disadvantage, namely, that should observations demand a change in any of the constants used, there is no means of making any correction in the results.

Delaunay's theory surmounted this difficulty, but at the expense of still greater inconvenience for making an ephemeris. The slow convergence of certain series involved an immense amount of labor to give sufficiently approximate results.

More recently, as the century was closing, Dr. Brown took up the subject and made a fresh attempt to calculate the motion of our satellite. It may be stated that he adopts all Delaunay's modifications of the problem and works them out algebraically; but there are many technical differences which it would be out of place to mention here.

Enough has been stated to show that there is not likely to be any breach of continuity in the treatment of this most important problem.

Another attack on the moon, and, incidentally, its motion, has recently been made by another analyst, Professor George Darwin; grappling with all the consequences of tidal friction, he has been able to present to us the past and future history of our satellite. Beginning as a part of the material congeries from which subsequently some fifty million years ago both earth and moon, as separate bodies, were formed, it has ever since been extending its orbit, and so retreating farther away from its centre of motion, while the period of the earth's rotation has been increasing at the same time, from a possible period of some three hours when the moon was born, to one of one thousand four hundred hours when the day and month will be equal, something like one hundred and fifty million years being 130 required for the process.

STELLAR EVOLUTION

It was only in the 80’s, after thousands of observations of the spectra of stars, nebulæ, and comets had been secured, that the full meaning of the revelations of the spectroscope began to dawn upon the world.

Before the introduction of spectrum analysis all stars were supposed to be suns, and the only difference recognized among them was one of brilliancy and the variation of brilliancy in the case of some of them.

It ultimately came out that great classes might be recognized by the differences of their spectra, which were ultimately traced to differences in their chemistry and in their temperature, as determined by the extension of the spectra in the ultra-violet, the whiter stars being hotter than the red ones, as a white-hot poker is hotter than a red-hot poker.

Next there was evidence to show that a large proportion of the stars were not stars at all like the sun, but swarms of meteorites; and in this way the mysterious new stars which appear from time to time in the heavens, and a large number of variable stars, were explained as arising from collisions among such swarms.

The inquiry which dealt with the spectroscopic results, having thus introduced the ideas of meteor swarms and collisions to explain many stellar phenomena, went further and showed that the various chemical changes observed in passing from star to star might also be explained by supposing the whole stellar constitution to arise from cool meteoritic swarms represented by nebulæ, the changes up to a certain point being explained by a rise of temperature due to condensation towards a centre. Here the new view was opposed to that of Laplace, advanced during the last century, that the stars were 131 produced by condensation and cooling; but Kelvin had shown, before the new view was enunciated, that Laplace’s view was contrary to thermodynamics, a branch of science which had developed since Laplace published his famous *Exposition du Système du Monde*.

After all the meteorites in the parent swarm had been condensed into the central gaseous mass, that mass had to cool. So that we had in the heavens not only stars more or less meteoritic in structure, of *rising* temperature, but stars chiefly gaseous, of falling temperature. It was obvious that representatives of both these classes of stars might have nearly the same mean effective temperature, and therefore more or less the same spectrum. A minute inquiry entirely justified these conclusions.

So far had the detailed chemistry of the stars been carried in the latter years of the century that the question of stellar evolution gave rise to that of inorganic evolution generally, the sequence in the phenomena of which can only be studied in the stars, for laboratory work without stint has shown that in them we have celestial furnaces, the heat of which transcends that of our most powerful electric sparks. In this way astronomy is paying the debt she owes to chemistry.

THE SUN AND HIS SYSTEM

Although the outer confines of space have, as we have seen, been compelled to bring their tribute of new knowledge by means of the penetrating power possessed by modern telescopes, and the cameras and spectroscopes attached to them, the study of the *near* has by no means been neglected, and for the reason that in astronomy especially we must content ourselves in the case of the more distant bodies by surmising what happens in them from the facts gathered in the region where alone 132 detailed observations are possible.

Thus what we can learn about the sun helps to explain what we discern much more dimly in the case of stars; a study of the moon’s face we are compelled to take as showing us the possibilities relating to the surface condition of other satellites so far removed from us that they only appear as points of light.

To begin, then, with the sun. Where a volume might be written, a few words must suffice. I have already stated that at the beginning of the nineteenth century the prevailing opinion was that it was a habitable globe. It was limited to the fiery ball we see. At the end of the century it is a body of the fiercest heat, and the ball we see is only a central portion of a huge and terribly interesting mechanism, the outer portions of which heave and throb every eleven years. Spots, prominences, corona, everything feels this throbbing.

Although the discovery of spots on the sun was among Galileo's first achievements, it was reserved for the last half of the nineteenth century to demonstrate their almost perfect periodicity.

Thanks to the labors of Schwabe, Wolf, Carrington, and De la Rue, Stewart, and Loewy, we now know that every eleven years the spots wax and wane; Tacchini and Ricco, during the last thirty years, have proved that the prominences follow suit, and the fact that the corona also obeys the same law was established during the American eclipse of 1878.

The study of solar physics consists in watching and recording the thermal, chemical, and other changes which accompany this period. Some of these effects can be best studied during those times when the ball itself is covered by the moon in an eclipse. Then the outer portions of the sun are revealed in all their beauty and majesty, and all the world goes to see.

But it is the quiet daily work in the laboratory which has enabled us to study the sun's place in 133
relation to the other stars, and so to found a chemical classification of all the stars that shine.

From the sun we may pass to his system, and first consider the nearest body to us—the moon.

While some astronomers have been discussing the movements and evolution of our satellite, others have been engaged upon maps of its surface, upon questions dealing with a lunar atmosphere, or a study of the origin of the present conformations and of possible changes. The science of selenology may be said to have been founded by Schröter at the beginning of the century, but it required the application of photography in later years to put it on a firm basis. Maps of the moon have been prepared by Lohrmann, Beer and Mädler, and Schmidt, the latter showing the positions of more than thirty thousand craters.

Very erroneous notions are held by some as to what we may hope to do in the examination of the moon's surface by a powerful telescope. A power of a thousand enables us to see it as if we were looking at York from London. It is recorded that Lassell once said that with his largest reflector in a "fit" of the finest definition he thought he might be able to detect whether a carpet as large as Lincoln's Inn Fields was round or square. Under these circumstances, then, we may well understand that the question of changes on the surface has been raised from time to time never to be absolutely settled one way or the other. By many the existence of an atmosphere is denied, and this is a condition which would negative changes, anything like the geological changes brought about on the surface of the earth, but the idea is now held by many that there is still an atmosphere, though of great tenuity.

The last few years of the century were rendered memorable from the lunar point of view by the 134
publication and minute study of a most admirable series of photographs of the moon obtained by the great equatorial Coudé of the Paris Observatory by Loewy and Puiseaux. One of the chief points aimed at has been to determine the sequence of the various events represented by the rills, craters, and walled plains, the mountain ranges and seas. This work is still in progress, the fourth part of the atlas being published in 1900; but enough has already appeared to indicate that the results of the inquiry when completed will be of the most important kind. The authors have already come to the conclusion that the lunar and terrestrial sea-bottoms much resemble each other, inasmuch as both have convex surfaces. The lunar seas began by sinking of vast regions; the formidable volcanic eruptions of which the moon has been the scene have taken place in times equivalent to those labelled "recent" in geological parlance. There is evidence that the axis of the moon has undergone great displacements, and four great periods of change have been made out. Finally they state that there is serious ground to believe that there is an atmosphere of some sort remaining.

It may readily be understood that with each increase of optical power new satellites of the various planets have been discovered. Soon after the discovery of Neptune a satellite was noted by Lassell. In

1846 both he and the eagle-eyed observer Dawes independently discovered another satellite (Hyperion) of Saturn. Lassell was rewarded in the next year by the discovery of two more satellites of Uranus; but, strangest observation of all, in 1877 Hall discovered at Washington two satellites of Mars some six or seven miles only in diameter, one of them revolving round the planet in seven and one-half hours at a distance of less than four thousand miles. As the day on Mars is not far different in duration from our own, this tiny satellite must rise in the west and south three times a day! 135

Wonderful as this discovery was, it is certainly not less wonderful when we consider it in connection with a passage in *Gulliver's Travels*, so true is it that truth is stranger than fiction. Swift, in his satirical reference to the inhabitants of Laputa, writes: "They have likewise discovered two lesser stars, or satellites, which revolve round Mars, whereof the innermost is distant from the centre of the primary planet exactly three of his diameters and the outermost five; the former revolves in the space of ten hours; and the latter in twenty-one and a half."

The last discovery of this kind has been that of an inner satellite of Jupiter by Barnard in 1892.

The planets from Mercury to Saturn were known to the ancients. I have already referred to the discovery of Uranus by Herschel's giant telescope, not long before the nineteenth century was born, and of Neptune, by analysis, towards the end of the first half of the century. With regard to what modern observations have done in regard to their physical appearance, the first place in general interest must be given to Saturn and Mars.

Saturn has always been regarded as the most interesting of the planetary family on account of its unique rings. Many subdivisions of the rings, and a dusky ring, first seen by Dawes and Bond, have been discovered during the last sixty years.

The meteoritic nature of the rings was suggested by Clerk Maxwell in 1857, and Keeler's demonstration of the truth of this view by means of the spectroscope, a few years ago, was brilliant in conception and execution.

But during the last half of the century the interest centred in Mars has been gradually increasing. The drawings made during the opposition of 1862, when compared with those made by Beer and Mädler (1830–40), made it perfectly clear that in this planet we had to deal with one strangely like our 136 own in many respects. There were obviously land and water surfaces; the snow at the poles melted in the summer-time; clouds were seen forming from time to time, and the changing tones of the water surfaces suggested fine and rough weather.

Afterwards came the revelation of the hawk-eyed Schiaparelli, beginning in the year 1877, and his wonderful map of the planet's surface. The land surfaces, instead of being unbroken, were cut up, as an English farm is cut up by hedges; straight lines of different breadths and tints crossed the land surfaces in all directions, and at times some of them appeared double. Schiaparelli naturally concluded that they were rivers—water channels—and being an Italian he used the appropriate word *canali*. This, unfortunately, as it turned out, was translated *canals*. Now canals are dug, *ergo* there were diggers. From this the demonstration, not of the habitability, but of the actual habitation, of Mars was a small step, and the best way of signalling to newly found kinsmen across some thirty millions of miles of space was discussed.

The world of science owes a debt of gratitude to Mr. Percival Lowell for having taken out to the pure air and low latitude of Arizona an eighteen-inch telescope for the sole purpose of accumulating facts tending to throw light upon this newly raised question. This he did in 1894. Schiaparelli has continued his magnificent observations through each opposition when the planet is most favorably situated for observation, and since 1896 Signor Cerulli, armed with a fifteen-inch Cooke, in the fine climate of Italy, has joined in the inquiry, so that facts are now being rapidly accumulated. It has been stated that markings similar to the strange so-called "canals" on Mars are to be seen on Mercury, 137 Venus, and even on the satellites of Jupiter. Mr. Percival Lowell does not hesitate to proclaim himself in favor of their being due, *in Mars*, to an intelligent system of irrigation. Signor Cerulli claims that *wherever seen* they are mere optical effects. We may be well content to leave to the twentieth century a general agreement on this interesting subject.

Finally, in our survey of our own system, come comets and meteor swarms. One of the most fruitful discoveries of the century, that comets are meteor swarms, we owe to the genius of Schiaparelli, A. H. Newton, and other workers on those tiny celestial messengers which give rise to the phenomena of "falling" or "shooting" stars.

The magnificent displays of 1799, 1833, 1866, and, alas! that which failed to come in 1899, we now know must be associated with Tempel's Comet. This is by no means the only case so far established; the connection will in the future be closer still when the orbits of the various swarms observed throughout the year shall be better known.

Comets which attract public attention by their brightness and grandeur of form are rather rare, and, in fact, only twenty-five of such have been seen since 1800. We have, however, with the great advance in instrumental equipment, been able to discover many which are scarcely visible to the naked eye, and this has swollen the number of comets very considerably. In the seventeenth century we find that only thirty-two were observed, while in the eighteenth this number was more than doubled (seventy-two). In the nineteenth century more than three hundred were placed on record, which is practically more than four times the number seen in the eighteenth.

The last great comet visible any considerable time was that discovered by Donati in 1858, and so carefully observed by Bond. It is unfortunate that since the importance, in so many directions, of spectroscopic observations of comets has been recognized they have been conspicuous by their 138
absence.

THE CONNECTION BETWEEN SOLAR AND TERRESTRIAL WEATHER

Everybody agrees that all the energy utilized on this planet of ours, with the single exception of that supplied by the tides, comes from the sun. We are all familiar with the changes due to the earth's daily rotation bringing us now on the side of our planet illuminated by the sun, then plunging us into darkness; that changes of season must necessarily follow from the earth's yearly journey round the sun is universally recognized.

On the other hand, it is a modern idea that those solar phenomena which prove to us considerable changes of temperature in the sun itself, may, and indeed should, be echoed by changes on our planet, giving us thereby an eleven-year period to be considered, as well as a year and a day.

This response of the earth to solar changes was first observed in the continuous records of those instruments which register for us the earth's magnetism at any one place. The magnetic effects were strongest when there were more spots, taking them as indicators of solar changes. Lamont first (without knowing it) made this out, at the beginning of the latter half of the century (1851), from the Göttingen observations of the daily range of the declination needle. Sabine the next year not only announced the same cycle in the violence of the "magnetic storms" observed at Toronto, but at once attributed them to solar influence, the two cycles running concurrently. It is now universally recognized that terrestrial magnetic effects, including auroræ, minutely echo the solar changes.

The eleven-year period is not one to be neglected.

Next comes the inquiry in relation to meteorology. Sir William Herschel, in the first year of the 139
century, when there were practically neither sun-spot nor rainfall observations available, did not hesitate to attack the question whether the price of wheat was affected by the many-or-few-spot solar condition. He found the price to be high when the sun was spotless, and *vice versa*.

By 1872, however, we had both rainfall and sun-spot observations, and the cycle of the latter had been made out. Meldrum, the most distinguished meteorologist living at the time, and others, pronounced that the rainfall was greatest at sun-spot maximum, and, further, that the greatest number of cyclones occurred in the East and West Indies at such times.

This result with regard to rainfall was not generally accepted, but Chambers showed shortly afterwards an undoubted connection between the cycles of solar spots and barometric pressure in the Indian area.

By means of a study of the widened lines observed in sun spots an attempt has been recently made to study the temperature, history of the sun since about 1877, and the years of mean temperature and when the heat was in excess (+) and defect (-) made out, have been as follows:

Heat condition	mean	+	mean	−	mean	+	mean	−	mean
Years	1869		1876		1881		1886–87		1891–92
		1870–75		1877–80		1882–86		1881–91	1892

Having these solar data, the next thing to do was to study the Indian rainfall during the southwest monsoon for the years 1877–1886, the object being to endeavor to ascertain if the + and − temperature pulses in the sun were echoed by + and − pulses of rainfall. The Indian rainfall was taken first because in the tropics the phenomena are known to be the simplest. It was found that in many parts of India the 140 + and − conditions of solar temperature were accompanied by + and − pulses, producing pressure changes and heavy rains in the Indian Ocean and the surrounding land. These occurred generally in the first year following the mean condition, that is, in 1877–78 and 1882–83.

The rainfalls at Mauritius, Cape Town, and Batavia were next collated to see if the pulses felt in India were traceable in other regions surrounding the Indian Ocean to the south and east. This was found to be the case.

A wider inquiry was followed, we are told, with equal success, so that we are justified in hoping that the question of the dependence of terrestrial upon solar weather has made a step in advance.

But just as the general public and practical men took little heed of the connection between sun spots and magnetism until experience taught them that telegraphic messages often could not “get through” when there were many sun spots, so the same public will not consider the connection in regard to meteorology unless the forecasting of droughts and famines be possible.

The recent work suggests that, if the recent advances in solar physics be considered, the inquiries regarding rainfall may be placed on a firmer basis than they could possibly have had in 1872, and that such forecastings may become possible.

What was looked for in 1872 was a change in the quantity of rain at maximum sun spots only, the idea being that there might be an effective change of solar temperature, either in excess or defect, at such times and that there would be a gradual and continuous variation from maximum to maximum.

We see that the rainfalls referred to above justify the conclusions derived from the recent work that two effects ought to be expected in a sun-spot cycle instead of one. There was excess of rainfall, 141 not only near the sun-spot maximum, but near the minimum.

If the authors of this communication to which I refer are right, then droughts and famines occur in India because the rain pulses, which are associated with the solar-heat pulses, are of short duration. When they cease the quantity of rain which falls in the Indian area is not sufficient, without water storage, for the purposes of agriculture; they are followed, therefore, by droughts, and at times subsequently by famines. They divide the period 1877—89 as under:

Rain from − pulse	1877. 1878. 1879 (part).
No rain pulse	1879 (part). 1880 (central year). 1881 (part).
Rain from + pulse	1881 (part). 1882. 1883. 1884 (part).
No rain pulse	1884 (part). 1885 } (central year). 1886 } 1887 (part).
Rain from − pulse	1887 (part). 1888. 1889.

Their statement is based on the fact that all the famines which have devastated India for the last seventy years have occurred at intervals of eleven years, or thereabouts, working backward and forward from the central years 1880 and 1885–86 in the above table, the middle years, that is, between the pulses.

Mr. Willcocks, in a paper read at the Meteorological Congress at Chicago, remarked that “famines 142
in India are generally years of low flood in Egypt.”

It is now pointed out that the highest Niles follow the years of the + and − pulses, as does the highest rainfall in the Indian area.

Even if these results, which were communicated to the Royal Society of London five weeks before the end of the century, be confirmed, it may be pointed out that Sir William Herschel’s suggestion of 1801 will have required a whole century for its fulfilment, so slowly do those branches of science move which have not already led to some practical development.

NORMAN LOCKYER.

145

PHILOSOPHY

It is a natural illusion that makes us think of each century as exhibiting the continuous development of one tendency of mind through a series of stages whose differences are only of secondary importance, and, on the other hand, to regard the steps from one century to another as corresponding to some marked transition of thought, as if the world had been suddenly precipitated into a new sphere of existence. For some purposes a rough generalization of this kind, that breaks at stated intervals the continuity of time, may, perhaps, be convenient. When, however, we begin to look at things more closely, we discover that it is impossible thus to cut through the historical connection of events, as it were, "with a hatchet." We discover, for example, that the characteristics of the eighteenth century were strongly marked only in one period of it; and that what we call the spirit of the nineteenth century was born some time before the year 1800, and has never quite prevailed over other tendencies. At the same time, there is an important difference indicated by these two loosely used names, and as it is always easier to define things by contrast, it may help us to make our subject more definite to consider what they mean.

I

It is too late now to "abuse the eighteenth century," which had its good and evil, like other periods. It is commonly conceived as the era of individualism and analysis, the era of logical [146] enlightenment and sceptical criticism; and, again, as the era of liberation from groundless superstitions and fictitious claims of authority; the era in which mankind seemed for the first time to throw off the weight of the past and to enter without fear upon the enjoyment of their earthly heritage. The science of Newton had given the last blow to the astronomy that made the earth the centre of the universe. It had undermined and discredited the simple theology that explained the whole material world as a cosmos arranged for the supply of human needs. At the same time, the progress of biology was bringing man to a consciousness that as a physical being he is only *primus inter pares* in the animal kingdom, and the decay of religious belief was making him realize his finitude, the limits of his natural existence, as, perhaps, he had never done before, at least never since the beginning of the Christian era. Earth seemed to be disconnected from heaven, and the human race thrown upon its own resources. By the new enlightenment all powers, ecclesiastical or political, were stripped of the mysterious sanctity that had once invested them. "The nimbus was taken away from the heads of the gods and rulers of the world." Every authority that claimed man's homage was weighed in the scales of the understanding, and, so weighed, every such authority was found wanting. The State had come to be regarded as only a collection of individuals who had agreed to live together under a ruler deriving all his claims from their consent, and invested with no divine right to their allegiance. The Church was no longer a sacred institution governed by priests who held their commission directly from God, but only a sort of spiritual police agency, an ally of the State in the restraint of vice and crime, or, at best, in Protestant countries, a society for mutual improvement. Men were "free and equal," each standing face [147] to face with his fellows, admitting no superiority or superstition of hero-worship in regard to any one of them. And the Deity, if his existence were not denied, tended to become a mere "Supreme Being," who was removed to such a distance from mankind that he could hardly be reached by their reverence, still less by their love.

At the same time, the influences which, in one point of view, seemed to limit and narrow human existence, in another point of view tended to liberate and enlarge it. If they excluded the idea of the infinite from man's life, they emancipated him from many degrading superstitions, which in an earlier

age had held him "all his lifetime subject to bondage." And as the pressure from above was lightened the individual seemed to become master of himself and of his destiny. If the king could no longer say, "*L'Etat c'est moi*," the rights of the subject were vindicated; if the authority of the Church was weakened, the bonds of free inquiry were broken; if imagination ceased to fill men with the awe and wonder of higher powers, the way was opened up for scientific and industrial development; if God was regarded as unknowable, "the proper study of mankind was man," and that study could now be pursued without fear or hinderance. Poetry and religion might be impoverished, the sense of the binding force of social relations might be weakened, but interest in the bettering of man's earthly condition was awakened, and with it came a new desire for justice to all, a new intolerance of human suffering, and a new demand that the lot of the class "which is most numerous and poor" should be made less wretched and insecure, and, towards the end of the century, a new turn was given to its leading thought, for an effort was made to discover in the nature of the individual himself the equivalent of those universal powers which the enlightenment had banished from the external world 148
and from the life of society. Rousseau carried individualism to an extreme point, at which it became its own correction, and taught men to find *within* their own souls the infinite which they could no longer discover *without*. Rejecting in the first instance all social conventions as unjust limitations of the natural man, and adopting the prevailing theory of the time, that the State is only the product of a contract between independent persons, he yet discovered in the individual thus liberated from all external pressure a "common reason," and "a general will," which could reorganize his life and bind him to his fellow-men and to God. This great idea, which appears in Rousseau rather as a stroke of insight, an intuition of genius—lifting him above his first thoughts and insensibly changing their meaning—was grasped by Kant as the principle of a new philosophy and worked out in a comprehensive system that dealt with all the great problems of thought and life. Kant, indeed, seemed, like Rousseau, to begin on the plane of eighteenth-century individualism, but, influenced as he was by the philosophy of Leibnitz, he from the first conceived the individual as in himself universal; or, to speak more exactly, as having a universal principle realized in him. Thus, though in one aspect of his being man is a finite object among other objects, confined within limits of space and time, and forming only a link in the chain of natural causation, in another aspect of it, as a conscious self, he is emancipated from all these limitations. For—such is Kant's argument—a knowing subject, for whom the whole finite world, including his own finite existence, is an object of knowledge, cannot himself be comprehended in that world or limited by any of its conditions. As there can be no world of objects except for a self, it is impossible that such a self should be merely one of these objects. Thus, as knowing, or capable of knowing, all things, man cannot be identified with any of them; or if, from one 149
point of view, as an individual, he is so identified, yet he has within him a universal principle that carries him beyond the limits of his individuality. And this contrast shows itself also in his practical life. For if as an object he appears to be but an animal organism, moved by the impressions of pleasure and pain which he receives from other objects, yet in his inner moral life man is revealed to himself as a self-determining subject, emancipated from all sensuous motives and from the necessity of nature which they bring with them, and conscious of subordination only to the law of duty, which is the law of his own reason. And that law, in spite of every pressure of circumstance from without, and of every impulse of passion from within, he knows that he ought to obey, and therefore he knows that he *can* obey it. Thus, in Kant's theory, the two extreme views of humanity, as natural and as spiritual, as limited to a finite individuality, hemmed in by necessities on every side, and yet as possessing a universal capacity of knowing, and an absolute power of self-determination, these two views are presented in sharp antithesis, and at the same time held together as different aspects of one life. In fact, we have here, as it were, compressed into a nutshell, the result of the whole history of eighteenth-century individualism, which began by depressing man and ended by exalting him; which, with one of its voices, seemed to reduce him to the level of an animal, a mere part of the partial world, a transitory phenomenal existence among other phenomena; and then, with its other voice, proceeded to recognize him as a member of the intelligible world, a "spectator of all time and existence," and gifted with the absolute freedom of a will which could be determined by nothing but itself. "The solitary," says Aristotle, "must be either a god or a beast," and the eighteenth century, in its conception of the 150
individual, seemed to oscillate between the one and the other till Kant, awaking to the impossibility of omitting either aspect of his being, demanded that he should be conceived as both at once. Kant thus

set the problem of the future; and if he did not solve it, he at least showed the futility of any narrow or one-sided solution and the direction in which an adequate solution could alone be sought. In short, Kant asked the question to which the nineteenth century, in all its philosophical reflection, has been striving to find an answer.

For in philosophy, as in other departments of knowledge, the work of the nineteenth century has been one of mediation and reconciliation. It has been an endeavor to break down the sharp antithesis of philosophical and scientific theories that was characteristic of an earlier time. In the writings of the greatest thinkers, the oppositions of materialism and spiritualism, of sensationalism and idealism, of empiricism and *a priori* speculation, of individualism and socialism, all the great oppositions of theoretical and practical philosophy, which formerly were held to be absolute and irreconcilable, have been modified, restated, reduced to the *relative* antagonism of the different aspects of one truth. The great controversies of the past have thus passed into a new phase, in which absolute statements *pro* and *con* have become, as it were, antiquated; and the question is no longer whether a particular doctrine or its opposite is true, but what are the elements of truth and error in each of them, and how we can attain to a comprehensive view of things, in which justice is done to both. And if it be asked, what are the principles or ideas that have suggested this reconciling work, and have been the guides of the greatest scientific or philosophic writers in attempting to achieve it, I think the answer must be that they are *the idea of organic unity*, and, as implied in that, *the idea of development*. Goethe and Hegel, in Germany; 151
Comte, in France; Darwin and Spencer, in England, are writers who almost span the whole range of difference in modern thought; but they, and a multitude of others in every department of study, have been inspired by the ideas of organism and development. And they have all used them somewhat in the same way to turn the edge of the old controversial weapons, or to lift thought above the "yes" and "no" of opposing dogmatisms. It is true that the definitions or interpretations of the ideas of organism and development given by these writers are very different, and often, indeed, so sharply opposed that they seem to bring back the old controversies in a new form. But this does not alter the significance of the general fact; for, in the first place, the use of an idea by any writer is by no means always limited by his own interpretation of it; and, in the second place, the true interpretation of the idea is that which contains the secret of its power and prevalence, and it must in the long run gain the victory over all other interpretations of it. We may, therefore, fairly say that these ideas have been the marked ideas of the century, the conscious or unconscious stimulus of its best thought; and that they have been working, and are working still, in the direction of a deeper and more comprehensive irenicon between the different tendencies of the human mind than has been attained in any previous stage of the history of philosophy.

Against such a general characterization of an age, there is the same objection which Burke indicated when he said that "he could not draw up an indictment against a nation." We are taking a distant and general view of a period, in which all its inequalities of movement, all the ebb and flow of opinion, are lost sight of, and only one main current of thought is visible. We may get a step nearer to the subject by distinguishing three periods in the century, in which there is a partial difference of 152
tendency. The first period, which we may roughly define as lasting well on into the 30's, is, in the main, a period of construction, of creative thought, in which the great germinating ideas that distinguished the century are more or less adequately expressed in different countries, and in which they receive a first, somewhat hasty, application to all departments of human knowledge. Idealistic philosophy, which gave the fullest expression to those ideas, seems for a time to carry all before it in Germany; and a similar movement of thought, less definitely reflective or speculative, enriches the literature of other countries. In the next period, lasting until the 70's, the new ideas do not lose their hold upon men's minds, but there is a certain critical recoil against them, a tendency to explain them away. The first premature synthesis of idealistic philosophy is attacked by a scepticism, which seems at times as if it would measure back the whole way to the individualistic materialism of an earlier age, or which only avoids that extreme to fall into a scientific agnosticism, at first sight even more hostile to the claims of philosophy. But the lesson of Kant could never be altogether forgotten, nor could the negative or sceptical tendencies of the *Critique of Pure Reason* be permanently separated from the positive results of his later writings. And the great scientific movement of the time, which at first seemed to draw away all interest from speculative inquiry, tended in the long run, especially by the

advance of biological study, to raise metaphysical questions which the methods of science were incapable of answering. Hence, in the latest decades of the century, there has come a revival of interest in philosophy, and especially in the idealistic philosophy of its first years. But if philosophy has revived, it is in a more critical and cautious form, and accompanied by a clear consciousness that the 153 only true idealism is that which is able to absorb and assimilate all the data supplied by empirical investigation, and do justice to all the results of the special sciences. The general movement of thought in the nineteenth century has thus, on the whole, taken an idealistic direction; but there has come with it also a deeper consciousness of the immense difficulty of a comprehensive synthesis; of the inefficacy of any easy monism or optimism, that would pluck the fruit of knowledge before it is ripe; of the infinite labor and patience, the sympathetic appreciation of the opposing views of others, and constant and unsparing criticism of our own, which are needed for the construction of a true philosophy.

II

In a short article like this, it is impossible to give more than a few indications of the way in which this three-fold *schema* of the history of nineteenth-century philosophy should be filled up. To give any definite impression, the writer must, so to speak, put on the seven-leagued boots of Jack the Giant Killer; in other words, however conscious he may be of the truth that *dolus latet in generalibus*, he must generalize and be content to mention only a few leading names in illustration of the tendencies of thought of which he speaks.

It is the instinct of each new generation to vindicate its freedom by rebelling against the authority of its predecessors; and when a new idea begins to influence human thought, it usually, on its first appearance, shows that side which is most antagonistic to the spirit of the past. Thus the peculiar nineteenth-century movement begins with a reassertion of the *universal* as against the *individual*, which is so emphatic that it looks like a return to Spinozism. Schelling is the most prominent philosophical representative of this tendency. In the works which he wrote about the beginning of the 154 century, he broke away even from the universalized individualism of Fichte, and gave emphatic prominence to the great philosophical commonplace—which had been almost forgotten by the previous age—that there is an identity which is below or above all distinction, and that the universe is one through all its multiplicity, and permanent through all its changes. His maxim—that there are none but *quantitative* differences in things, and that all these, even the difference of mind and matter, disappear in the "indifference" of the Absolute—was like a declaration of war against the "enlightenment." It meant that philosophy was no longer content to regard the whole as the sum of the parts, but could look upon the distinction of the parts only as a differentiation of the whole. With Schelling, indeed, this differentiation was in danger of being reduced to a mere appearance and the unity of the Absolute was on the point of vanishing in a bare or abstract identity. But his strong assertion of the unity beneath all difference, of the priority of the universal to all particulars, was perhaps necessary, ere the true conception of the organic unity of the world could be arrived at. And the correction soon came with Hegel, who maintained that the absolute is "not substance, but subject." For this meant that the absolute is a self-differentiating principle, realizing itself in a world of difference which is no mere appearance, but its own essential manifestation; and again—what is the counterpart or complementary truth to this—that in the world there are "degrees of reality," and that "mind is higher in degree than nature." But these ideas could hardly have been understood until the uncompromising assertion of the absolute unity had been made, and until the subjectivity of the Kantian and Fichtean points of view had once for all been set aside.

The philosophy of Hegel derives its power from the way in which it strikes what, as I have already 155 said, was the key-note of the nineteenth-century philosophy. In the first place, it is a philosophy of reconciliation, which attempts, through a criticism of the oppositions of philosophical theory, to reach a point of view in which they are all seen to be subordinated to the unity of one principle. His attack upon the "law of contradiction," as formulated by scholastic logicians, meant simply that absolute

distinctions are unmeaning, and that the only real differences are differences within a unity. On this principle he tried to show that all the oppositions of thought and things which have found expression in philosophy are relative oppositions, which find a solution or reconciliation in the life and movement of the whole. Hence he maintained that in all the great controversies that have divided the world, in metaphysics and psychology, in ethics and theology, the combatants have really been co-operators. Both sides, to use the expression of Leibnitz, have been "right in what they affirmed and wrong only in what they denied." And their conflict has been the means of the evolution of a fuller truth than that which was contained in the doctrine of either party. In the second place, Hegel is guided throughout by the conception of the universe—and, in a sense, of every even relatively independent existence in it—as an organism, every element in which implies the whole, every change in which is a phase of its self-evolution. For his logical doctrine of the "*notion*" (as *Begriff* is commonly translated) means simply that we do not see anything truly until we comprehend it as a whole, in which one principle manifests itself through all the difference of the parts and—just through their distinctions and their relations—binds itself into one individual—reality. In this sense, everything just so far as it has an independent individual existence at all is an organism. Lastly, while thus conceiving the universe as organic, Hegel 156
maintained that it is not a natural but a spiritual organism. For the limited scope of a natural organism and its process cannot be regarded as commensurate with a universe, which comprehends all existence, whether classed as organic or inorganic. Only the conscious and self-conscious unity of mind can overreach and overcome such extreme antagonisms, and reduce them all to elements in the realization of its own life. We must, therefore, think of the universe as an organism which includes nature, but manifests its ultimate principle only in the life of man. We may add that in all this Hegel attempted to show that he was only working out in the sphere of speculative thought what Christianity had already expressed for the ordinary consciousness, according to its half-pictorial methods of representation.

While this is the general meaning of Hegelianism, it must be added that Hegel was more successful in formulating these ideas in their logical or metaphysical form than in applying them to the results of the special sciences of nature, which he only knew at second hand; or even to the different provinces of the spiritual life and history of man, which he had studied more thoroughly. In both cases his data were very incomplete, and the scientific interpretation of them had not then been carried far enough to prepare—as, according to Hegel himself, it should prepare—for the final interpretation of philosophy. There is another circumstance to be taken into account, a circumstance which deeply affected Hegel and all the writers of his time. In the slow process of human history the new wine is always at first poured into old bottles, and only when the old bottles burst is an effort made to find new ones that will contain it safely. Hence the development of the new spirit in philosophy seemed often to go hand-in-hand with a movement of restoration in politics and religion which was not easily 157
distinguishable from reaction. Just as the politicians of the time could find for the newly awakened spirit of nationality no other embodiment than the institutions of the ancient *régime*, and tried to revive the old system destroyed by the Revolution, with only a few repairs and additions, so the great philosophical writers sought generally to reanimate the old scheme of life and thought by means of the new ideas, rather than completely to recast it in accordance with them. Hence, although Hegel's *principle* of evolution was as hostile to reaction as to revolution, as hostile to an authoritative system that denied the rights of the individual as to mere individualism, his particular doctrines, both in politics and theology, took a strongly conservative tinge. When we look more closely we see that it is only as restoration is at the same time reformation, as it makes the old forms the expression of a new life, that Hegel could logically defend them. But the form which he gave to his ideas was perplexing; it tended in many minds to identify the principle of development, which means that the future can only spring *out* of the past and the present, with the defence of the *status quo* in Church and State; and, on the other hand, to confuse the forces of progress with those of revolution. Thus the mediating, reconciling power of the new doctrine was for a time obscured, and its effect in raising men's minds above the old levels of controversy was delayed.

III

In other countries during the earlier decades of the century a similar movement of thought is discernible, though it was not carried out anywhere with the same philosophical thoroughness as in Germany. In France the organic idea did not find any very powerful representative till the time of 158 Comte, and even in his expression of it there is a certain ambiguity. In his well-known law of development, indeed, he seems to reproduce the individualistic doctrine of the eighteenth century, and to deny the reality of the *universal*, both in its theological and its philosophical form. But already in the last volume of his *Positive Philosophy*, when he begins to deal with human society, he maintains that "the individual man is an abstraction, and that there is nothing real but humanity"; and in his *Positive Politics* he treats this unity of mankind as not only real, but divine. In that work, moreover, he makes another step. Rejecting at once the obstructions of the individualists and those of the socialists, he rises to the conception of a social organism, which gives play to the competitive energy of individuals, and yet binds them together in its own more comprehensive life. In England, before the close of the eighteenth century, the same spirit had found a representative in Burke, who rejected entirely the idea of a social contract, and maintained that the State is based on an unconscious reason of society, which is far wiser than the conscious reason of even the wisest individuals. In general, however, the spiritualistic movement of the earlier part of the century took, among the English-speaking people, rather a poetic and literary than a philosophical form. And the imperfect attempts of Coleridge to transplant German ideas into England—attempts followed up with signal energy by Frederic Denison Maurice—hardly constitute an exception to this rule. In this connection, also, as one who partly grasped the organic idea of social life and its development, but who gave it a somewhat imperfect and even contradictory expression, I may mention a later writer, Thomas Carlyle, whose imaginative genius and moral enthusiasm did much to breathe a new life into history. Though not a 159 philosopher in any technical sense, he was, like his friend Emerson, a vehicle of philosophical ideas, and he contributed greatly to scatter the seed of idealism upon British soil. His Calvinistic pessimism, indeed, makes a curious contrast with the fearless optimism of the new country which is characteristic of Emerson; but whether great men are to be regarded as "heroes to be worshipped," according to the teaching of the one, or as "representative men," who are to be followed because they express what all are thinking, according to the ideas of the other, we are led, in both cases, to a deeper view of the solidarity of human society and of its spiritual basis.

IV

It is difficult to determine more than approximately the beginning of special movements of thought; for the different nations of the civilized world are not exactly contemporaneous in their development, and in each nation there are always individuals who lag behind the time or hasten on before it. But, speaking generally, we may say that as early as the fourth decade of the century a certain reaction had set in against the conclusions of idealistic philosophy, and especially against the organic idea of human life; and a tendency was even shown to revert, so far as possible, to the methods and ideas of the eighteenth century. The reasons for this change are various. In Germany the succession of great philosophers had come to an end, and their followers were smaller men, who were inclined too much to repeat the formulas, but had little of the creative power, of their predecessors. More attention, therefore, began to be paid to the protests of writers like Herbart and Schopenhauer, who, even in the hour of its triumph, had criticised and attacked the prevailing philosophy. Again, the 160 physical sciences were advancing by "leaps and bounds," and there was a growing inclination to believe in the universal validity of the mechanical methods of explanation to which *they* owed their success, and even in those sociological and historical studies to which the idealistic philosophy had given so great an impetus. The progress of empirical research and the increase of the materials of knowledge caused much of the work of Hegel and his followers to seem inadequate, if not entirely to set it aside. Even in Germany, where the new ideas had taken a distinctly philosophical shape, they seemed to lose their hold in the controversies that attended the breaking up of the Hegelian school; and in other countries, where they never found such a systematic expression, they were even less able to resist the attack now made upon them. Furthermore, as I have already indicated, writers of an idealistic tendency, in their recoil from the enlightenment, had devoted themselves so much to an appreciation of institutions derived from the past that they seemed to have no eyes for the defects of these institutions, and to confuse evolution with restoration.

The general result of all these influences was, then, to discredit philosophy and exalt science, so far as might be, into its place. Either the abstract methods of the physical sciences were proclaimed as adequate for the discovery of all truth, or, if this was seen to be impossible, agnosticism was professed in regard to all subjects to which these methods could not be applied. Even the phenomena of life were supposed to be capable of explanation by the action and reaction of the parts or elements of the physical organism, and Huxley looked forward to the time when man with all his spiritual endowments should be shown to be only the "cunningest of nature's clocks." The new science of psychophysics, 161
which arose in Germany and has been cultivated with so much zeal by Wundt and others in all civilized countries, seemed to carry the method of physics into the investigation of mind, and some of its students were ready to maintain that it was the only psychology that deserved the name of science. Darwin's great work on the *Origin of Species*, in so far as it set aside the idea of special creation and referred the "purposiveness" of organic structures to a process in which the external environment, and not any inward power of self-adaptation, was the controlling factor, seemed to bring a new reinforcement to the same way of thinking. And he and his followers were not slow to apply the theory of natural selection to the life of man, as well as to that of plants and animals. Finally, the historical studies, which were now cultivated with an energy to an extent hitherto unexampled, and immensely extended the knowledge of the process whereby the present has grown out of the past, were invaded by a similar spirit; and the historical method was maintained to be a solvent which could disintegrate all metaphysical conceptions of ethics or politics or even of theology. The account of the genesis of any idea was regarded as reducing its claims to the level of the elements or rudiments out of which it had sprung, and thus as enabling the scientific historian to explain, or explain away, the spiritual by the natural in all human life and experience. All things appeared again to be pointing towards a system of thought which would resolve ethics and psychology into physiology, and physiology into chemistry and physics.

At the same time the victory of this tendency was always more apparent than real. In the first place, "out of the eater came forth meat"—that very advance of the special sciences, which in its earlier stages had tended to throw all speculative thought into the shade, in the long run caused the need of philosophy to be again felt. In particular, the study of development in the organic world, which 162
had received so great a stimulus from the work of Darwin, could not be carried on without the aid of higher conceptions than were required for the guidance of the physicist. The hypothesis of natural selection might expel the idea of design in the cruder form of a special creation of every distinct species; and the emphasis which it had laid upon the outward conditions of growth might seem unfavorable to the higher conception of an immanent teleology of the organism, but it was confessed by its author to be an incomplete theory of development, and Darwin himself, when he turned his attention to the evolution of man, found it necessary to supplement it by what might be called the converse theory of sexual selection; thus adding a principle of co-operation to his first principle of competition. And Mr. Spencer, who defined growth as a process of integration and differentiation, little as he might himself intend it, was really putting into popular language the Hegelian idea of evolution—an idea which necessarily involved the conception of a self-determined end. Evolutionists might cling, as they still cling, to the belief that, though constantly and necessarily speaking of purpose, they could eliminate it from the result of their investigations by the hypothesis of Darwin, or, subsequently, of Weissmann; but their discussions, especially when they were extended to the historical development of man, could not but reawaken the great controversy whether in the *ultimate* explanation of things it is more reasonable to "level up," or to "level down," to explain the higher by the lower, or the lower by the higher. That both explanations are necessary, nay, that no teleology can be of much worth which does not presuppose a thorough inquiry into the causal connections of particular phenomena, was admitted by all modern idealists. But they began to press the question whether the unity of the whole is not prior to its distribution into parts, and does not govern their 163
relations with each other; and, in particular, whether it is possible in the case of organic beings, and especially of organic beings possessed of consciousness and self-consciousness, to be satisfied with a

mode of explanation that treats them as mere collections of material elements which act and react externally upon each other. Whatever its value as a provisional hypothesis, can such a mode of explanation be finally regarded as adequate for the explanation of the nature of the world as a whole, or, indeed, of any one existence in it, that has even a relative independence or separate being of its own?

But, in the second place, a revival of the idealistic philosophy was made necessary by an obvious weakness which clung to the scientific materialism of the nineteenth century from the very beginning. The Kantian criticism of knowledge, which could not be entirely neglected, had convincingly proved that in our experience objects can be known only in relation to a subject, and matter only in relation to mind. But, if so, how could the latter be explained by the former? Even to those who had not fully understood this doctrine, it became evident that mind is at least co-ordinate with matter, and cannot be treated as a mere "*epiphenomenon*" of it. Mr. Spencer, therefore, had to take refuge in the strange notion that we are possessed of "two consciousnesses": the consciousness of ideas within us, and the consciousness of motions without us; and that neither of these can be resolved into the other, though both are the phenomena of an unknowable Absolute. It is in this citadel of ignorance that Huxley tries to intrench himself; but the place was taken before it could be occupied. The self-contradiction of an unknowable Absolute, and the equal though less obvious self-contradiction of a dualistic separation between two aspects of our life—which, as a matter of fact, are never, and logically can never be, 164
divided—could not long be maintained against a criticism armed with the weapons of Kant and his idealistic successors. Already, in the 50's, the cry "Back to Kant" was raised in Germany, and, not long after, it led in England and America to a renewed study of the German idealistic writers, in which Dr. Hutchison Sterling and the late Professor Green took a leading part. It was soon obvious to every one who had learned the lesson of critical philosophy that the agnostic dualism of Mr. Spencer was due to a fundamental misconception of what is meant by the subjectivity of knowledge. It was pointed out that if we have the consciousness of object and subject only in relation to each other, it is not necessary to seek for the principle of their unity in any *Tertium Quid* which is neither the one nor the other. That which Mr. Spencer sought in an unknowable Absolute was "in our mouths and in our hearts"; it was to be found in the inseparable unity of experience, in which the inward and the outward are correlative elements. Agnosticism was a sort of spiritual refuge for the destitute constructed by those who had renounced their heritage: who, in other words, had by their abstractions separated the elements of experience from each other, and were thus forced to seek beyond experience for the unity which they had lost. The true remedy for the evil was to give up such abstract ways of thinking and to learn to "think things together"; in other words, to recognize the organic relation of the inner and the outer life, and to explain the parts by the whole, and not the whole by the artificially severed parts.

V

The great distinguishing feature of the last two decades of the century has been a movement of approximation, partly conscious and partly unconscious, between the representatives of science, and 165
particularly of those sciences that deal with special aspects or elements of human life, on the one hand, and the representatives of idealistic philosophy on the other. The reconciling ideas of an earlier time have become better understood and have shown more effectively their power to reconcile. Not that this mediating power had previously been entirely unfelt. Even in the time when philosophy was most discredited in Germany, Lotze, in whom a cautious critical temper was combined with deep moral and religious sympathies, and a practical knowledge of the biological and medical sciences with careful studies of Kant and Hegel, sought to show how an idealistic view of the universe and of human life could be maintained consistently with the fullest recognition of scientific methods and results. And though his system was, on the whole, rather a compromise than a true reconciliation of philosophy and science, yet it has undoubtedly had very great influence in modifying the ideas of the opposing schools of thought and narrowing the ground of controversy between them. Thus the old English empirical psychology, which was represented by the Mills and by Mr. Bain, has gradually widened its scope in the hands of writers like Professor Ward and Mr. Stout, at first probably through the study of Herbart

and then by contact with the revived idealistic movement. On the other hand, we may notice how idealistic writers, like Mr. Bradley and Mr. Bosanquet, have tried to absorb every lesson that can be learned from empiricism, and to shun with the utmost care the very suspicion of anything like dogmatism. Mr. Bradley's denunciations of a "too easy monism" and a philosophy that turns the living world into a "ballet of bloodless categories" are too well known to be more than referred to. Nor is this the place to discuss whether his fear of such a result has not sometimes led him into compromises 166
which are inconsistent with his own fundamental principle that the world must be conceived as an intelligible system. In any case, we may fairly point to his work and to the work of other writers animated by a similar spirit, as showing the growing prevalence of that reconciling spirit which seeks at once to do justice to all the results of empirical inquiry and of the investigations of the special sciences, and yet at the same time to give them a new interpretation in the light of an idealistic philosophy. It is impossible within our limits to illustrate this view of the tendencies of the time by further reference to the recent philosophical literature of England and America, or of Germany and France. Still less can I refer to the numerous books on special departments of inquiry in ethics and theology, in sociology and in history, in which the "ideally organic view of life and the world," as we may call it, has shown its mediating and reconciling influence. Nor can I do more than refer to the counter current of pessimism, which has found its most distinguished representatives in Hartmann and Nietzsche; the former a man of great wealth of thought and dialectical power, whose philosophy is idealistic in all but its ultimate principle, and is indeed pessimistic only by an exaggeration of the opposition between the conscious and the unconscious working of reason; the latter, hardly a philosopher at all but rather a writer of pungent and suggestive aphorisms, winged with indignant passion against prevalent opinions—aphorisms which always contradict some one, and often contradict each other. From Nietzsche at his best we may receive a useful warning against too easily satisfying ourselves with the commonplaces of idealistic optimism; from Hartmann we may derive very considerable help in estimating the difficulties that have to be met by those who would seek to 167
work out idealistic principles into a systematic view of the world. But, without attempting to enter upon any more detailed criticism of these or other important writers of recent years, I shall devote the space that remains to one general thought as to the present state of controversy, in relation to the fundamental principles of philosophy.

VI

Ever since the revival of the study of Kant, the main conflict in philosophy has ceased to lie between materialism and idealism. It has rather become a conflict between those who take up some position analogous to that of Kant and those who seek to carry out the idealistic principle to all its consequences. For the essential characteristic of Kant's position lay in his sharp division between the spheres of knowledge and of faith—between a knowledge which was confined to phenomena and their connection in experience, and a faith of practical reason, which reached beyond experience to apprehend that which is noumenally real. Even the agnosticism of Mr. Spencer might be regarded as a modification of the Kantian point of view, in so far as his denial of the possibility of knowing the absolute is based on Mansel's version of the Kantian antinomies; while his description of the "vague consciousness" of the absolute which he bids us worship may be regarded as representing that faith which, in Kant's view, enables us to pierce the veil of the phenomena and grasp the ultimate reality of things. And in the latter part of the century there has been a continual germination of similar theories, theories agreeing with the Kantian philosophy at least in making some kind of dualistic division between the sphere of clearly defined knowledge and the sphere of ideal or spiritual faith, and also in confining the former to phenomena while the latter is held to be capable of rising in some way from 168
the phenomenal to the real. One of the earliest fruits of the Neo-Kantian movement in Germany was Lange's *History of Materialism*, which insisted on the strictest interpretation of the lesson of the *Critique of Pure Reason*, that scientific knowledge is confined to the empirical and phenomenal, but which maintained also the chartered freedom of imagination to feed our hopes with the idea of a world not realized, or realizable, under the conditions of finite experience. And, with a different aim, but in a

similar spirit, Ritschl, borrowing some of his weapons from Lotze, sought to take away from philosophy the right to investigate the spiritual truths of religion, and maintained that such truths were given in a kind of intuition of faith which is above criticism and which some of his followers identify, like Kant, with the demands or postulates of the moral consciousness. Other writers, following Schopenhauer, have sought to emancipate the will from the intelligence and to give it an independent power of estimating values. The great effort to bring science and philosophy together—which, as we have seen, has characterized the later years of the century—has itself naturally given rise to many such dualistic compromises, of which Lotze's philosophy was among the earliest. And it is partly to Lotze's influence that we owe the tendency, visible in some of the most important recent contributions to philosophy, to regard our actual experience as having an intuitive completeness which is beyond all analysis, while reflective thought on the other hand is conceived as having a purely analytic and discursive operation, which can grasp only the severed fragments of the given reality and connect them externally to each other, but which can never restore the organic whole again. Here, too, we seem by another way to be landed in the same conclusion, viz., that we are perpetually poised between an 169
ideal which we cannot verify, but which yet is held to be our only vision of reality, and a definite result of knowledge, which only gives us what is abstract and phenomenal. Yet it is difficult to understand how such an organic idea of the universe can exist except for the thinking intelligence, and how the thought that grasps it can be separated from the discursive thought by which the different elements of reality are brought into relation. How, indeed, can there be any thought which is not both discursive and intuitive at once, any thought which connects the parts without resting upon the unity of the whole to which they belong?

All these different compromises are really different forms of the Kantian dualism, but they supply convenient cities of refuge for those who are unwilling to admit that faith is but implicit reason, and that it is always possible to translate its intuitions of truth into explicit logic. There is much excuse, indeed, in many cases for such unwillingness when we consider how often reason has presented itself as purely a critical or dissolving power, and how often abstract theories which grasp only one aspect of things have been set forth as complete explanations of religion or morality or some other of the higher interests of life. It has always to be kept in view that it is in something like immediate perception that truth is given in the first instance, and that philosophy, therefore, must always be in a sense toiling after the intuitions of faith. Yet, on the other hand, to hold that there is anywhere an abstract division between the two is to hold that faith is essentially irrational; it is to exalt it above reason in a way that inevitably leads in the end to its being depressed below reason. If, however, this view can be maintained it must lead in the long run to the rejection of all dualistic compromises. And there are already many who hold that after the unstable equilibrium of the Kantian theory has been shaken there 170
is no secure standing-ground for philosophy short of a thorough-going idealism. Yet even they have learned by experience how dangerous it is to snatch prematurely at the readiest idealistic interpretation of facts; and they are aware how easy it is to fall into a simple optimistic theory, which slurs over difficulties instead of solving them. They know that if Hegel or any one ever pretended, or could reasonably be interpreted as pretending, to construe the universe *a priori*, the pretence was futile, and that a true and valuable idealism can be reached only through the interpretation of the data of experience by the special sciences, and the reinterpretation of the results of these sciences by philosophy. They hold, in short, that if the well-known saying of Hegel is to be taken for truth, both of its clauses must be equally emphasized, and that no philosophy can safely maintain that "what is rational is actual" which has not gone through all the effort that is necessary to prove that "what is actual is rational."

EDWARD CAIRD.

MEDICINE

INTRODUCTION

For countless generations the prophets and kings of humanity have desired to see the things which men have seen, and to hear the things which men have heard in the course of the wonderful nineteenth century. To the call of the watchers on the towers of progress there had been the one sad answer—the people sit in darkness and in the shadow of death. Politically, socially, and morally the race had improved, but for the unit, for the individual, there was little hope. Cold philosophy shed a glimmer of light on his path, religion in its various guises illumined his sad heart, but neither availed to lift the curse of suffering from the sin-begotten son of Adam. In the fulness of time, long expected, long delayed, at last Science emptied upon him from the horn of Amalthea blessings which cannot be enumerated, blessings which have made the century forever memorable; and which have followed each other with a rapidity so bewildering that we know not what next to expect. To us in the medical profession, who deal with this unit, and measure progress by the law of the greatest happiness to the greatest number, to us whose work is with the sick and suffering, the great boon of this wonderful century, with which no other can be compared, is the fact that the leaves of the tree of Science have been for the healing of the nations. Measure as we may the progress of the world—materially, in the advantages of steam, electricity, and other mechanical appliances; sociologically, in the great 174 improvement in the conditions of life; intellectually, in the diffusion of education; morally, in a possibly higher standard of ethics—there is no one measure which can compare with the decrease of physical suffering in man, woman, and child when stricken by disease or accident. This is the one fact of supreme personal import to every one of us. This is the Promethean gift of the century to man.

THE GROWTH OF SCIENTIFIC MEDICINE

The century opened auspiciously, and those who were awake saw signs of the dawn. The spirit of Science was brooding on the waters. In England the influence of John Hunter stimulated the younger men to the study of the problems of anatomy and pathology. On the Continent the great Boorhaave—the Batavian Hippocrates—had taught correct ways in the study of the clinical aspects of disease, and the work of Haller had given a great impetus to physiology. The researches of Morgagni had, as Virchow had remarked, introduced anatomical thinking into medicine. But theories still controlled practice. Under the teaching of Cullen, the old idea that humors were the seat of disease had given place to a neuro-pathology which recognized the paramount influence of the nervous system in disease. His colleague at Edinburgh, Brown, brought forward the attractive theory that all diseases could be divided into two groups, the one caused by excess of excitement—the sthenic—the other by a deficiency—the asthenic—each having its appropriate treatment, the one by depletion, the other by stimulation. In a certain measure Hahnemann’s theory of homœopathy was a reaction against the prevalent theories of the day, and has survived through the century, though in a much modified form. Some of his views were as follows:

“The only vocation of the physician is to heal; theoretical knowledge is of no use. In a case of 175 sickness he should only know what is curable and the remedies. Of the diseases he cannot know anything except the symptoms. There are internal changes, but it is impossible to learn what they are; symptoms alone are accessible; with their removal by remedies the disease is removed. Their effects can be studied in the healthy only. They act on the sick by causing a disease similar to that which is to be combated, and which dissolves itself into this similar affection. The full doses required to cause symptoms in the well are too large to be employed as remedies for the sick. The healing power of a drug grows in an inverse proportion to its substance. He says, literally: 'Only potencies are homœopathic medicines.' 'I recognize nobody as my follower but him who gives medicine in so small doses as to preclude the perception of anything medicinal in them by means either of the senses or of chemistry.' 'The pellets may be held near the young infant when asleep.' 'Gliding the hand over the patient will cure him, provided the manipulation is done with firm intention to render as much good with it as possible, for its power is in the benevolent will of the manipulator.' Such is the homœopathy of Hahnemann, which is no longer recognized in what they call homœopathy to-day."—(A. Jacobi.)

The awakening came in France. In 1801 Bichat, a young man, published a work on general anatomy, in which he placed the seat of disease, not in the organs, but in the tissues or fabrics of which they were composed, which gave an extraordinary impetus to the investigation of pathological changes. Meanwhile, the study of the appearances of organs and bodies when diseased (morbid anatomy), which had been prosecuted with vigor by Morgagni in the eighteenth century, had been carried on actively in Great Britain and on the Continent, and the work of Broussais stimulated a more 176
accurate investigation of local disorders. The discovery by Laennec of the art of auscultation, by which, through changes in the normal sounds within the chest, various diseases of the heart and lungs could be recognized, gave an immense impetus to clinical research. The art of percussion, discovered by Avenbrugger in the eighteenth century, and reintroduced by Corvisart, contributed not a little to the same. Laennec's contributions to the study of diseases of the lungs, of the heart, and of the abdominal organs really laid the foundation of modern clinical medicine. A little later Bright published his researches on diseases of the kidneys, from which we date our knowledge of this important subject. One of the most complicated problems of the first half of the century related to the differentiation of the fevers. The eruptive fevers, measles, scarlet fever, and small-pox, were easily recognized, and the great group of malarial fevers was well known; but there remained the large class of continued fevers, which had been a source of worry and dispute for many generations. Louis clearly differentiated typhoid fever, and by the work of his American pupils, W. W. Gerhard and Alfred Stillé, of Philadelphia, and George B. Shattuck, of Boston, typhus and typhoid fevers were defined as separate and independent affections. Relapsing fever, yellow fever, dengue, etc., were also distinguished. The work of Graves and Stokes, of Dublin, of Jenner and Budd, in England, of Drake, Dickson, and Flint, in America, supplemented the labors of the French physicians, and by the year 1860 the profession had reached a sure and safe position on the question of the clinical aspects of fevers.

The most distinguishing feature of the scientific medicine of the century has been the phenomenal results which have followed *experimental investigations*. While this method of research is not new, since it was introduced by Galen, perfected by Harvey, and carried on by Hunter, it was not until well 177
into the middle of the century that, by the growth of research laboratories, the method exercised a deep influence on progress. The lines of experimental research have sought to determine the functions of the organs in health, the conditions under which perversion of these functions occur in diseases, and the possibility of exercising protective and curative influences on the processes of disease.

The researches of the physiological laboratories have enlarged in every direction our knowledge of the great functions of life—digestion, assimilation, circulation, respiration, and excretion. Perhaps in no department have the results been more surprising than in the growth of our knowledge of the functions of the brain and nerves. Not only has experimental science given us clear and accurate data upon the localization of certain functions of the brain and of the paths of sensatory and of motor impulses, but it has opened an entirely new field in the diagnosis and treatment of the diseases of these organs, in certain directions of a most practical nature, enabling us to resort to measures of relief undreamed of even thirty years ago.

The study of physiology and pathology within the past half-century has done more to emancipate medicine from routine and the thraldom of authority than all the work of all the physicians from the days of Hippocrates to Jenner, and we are as yet but on the threshold.

THE GROWTH OF SPECIALISM

The restriction of the energies of trained students to narrow fields in science, while not without its faults, has been the most important single factor in the remarkable expansion of our knowledge. Against the disadvantages in a loss of breadth and harmony there is the compensatory benefit of a 178 greater accuracy in the application of knowledge in specialism, as is well illustrated in the cultivation of special branches of practice. Diseases of the skin, of the eye, of the ear, of the throat, of the teeth, diseases of women and of children, are now studied and practised by men who devote all their time to one limited field of work. While not without minor evils, this custom has yielded some of the great triumphs of the profession. Dentistry, ophthalmology, and gynæcology are branches which have been brought to a state of comparative perfection, and very largely by the labors of American physicians. In the last-named branch the blessings which have been brought to suffering women are incalculable, not only as regards the minor ailments of life, but in the graver and more critical accidents to which the sex is liable.

One of the most remarkable and beneficial reforms of the century has been in the attitude of the profession and the public to the subject of insanity, and the gradual formation of a body of men in the profession who labor to find out the cause and means of relief of this most distressing of all human maladies. The reform movement inaugurated by Tuke in England, by Rush in the United States, by Pinel and Esquirol in France, and by Jacobi and Hasse in Germany, has spread to all civilized countries, and has led not only to an amelioration and improvement in the care of the insane, but to a scientific study of the subject which has already been productive of much good. In this country, while the treatment of the insane is careful and humanitarian, the unfortunate affiliation of insanity with politics is still in many States a serious hinderance to progress.

It may be interesting to take a glance at the state of medicine in this country at the opening of the nineteenth century. There were only three schools of medicine, the most important of which were the University of Pennsylvania and the Harvard. There were only two general hospitals. The medical 179 education was chiefly in the hands of the practitioners, who took students as apprentices for a certain number of years. The well-to-do students and those wishing a better class of education went to Edinburgh or London. There were only two or three medical journals, and very few books had been published in the country, and the profession was dependent entirely upon translations from the French and upon English works. The only medical libraries were in connection with the Pennsylvania Hospital and the New York Hospital. The leading practitioners in the early years were Rush and Physick, in Philadelphia; Hossack and Mitchill, in New York; and James Jackson and John Collins Warren, in Boston. There were throughout the country, in smaller places, men of great capabilities and energy, such as Nathan Smith, the founder of the Medical Schools of Dartmouth and of Yale, and Daniel Drake in Cincinnati. After 1830 a remarkable change took place in the profession, owing to the leaven of French science brought back from Paris by American students. Between 1840 and 1870 there was a great increase in the number of medical schools, but the general standard of education was low—lower, indeed, than had ever before been reached in the medical profession. The private schools multiplied rapidly, diplomas were given on short two-year sessions, and nothing contributed more to the degeneration of the profession than this competition and rivalry between ill-equipped medical schools. The reformation, which started at Harvard shortly after 1870, spread over the entire country, and the rapid evolution of the medical school has been one of the most striking phenomena in the history of medicine in the century. University authorities began to appreciate the fact that medicine was a great department of knowledge, to be cultivated as a science and promoted as an art. Wealthy 180 men felt that in no better way could they contribute to the progress of the race than by the establishment of laboratories for the study of disease and hospitals for the care of the sick poor. The benefactions of Johns Hopkins, of Sims, of Vanderbilt, of Pierpont Morgan, of Strathcona, of Mount-Stephen, of Payne, and of Levi C. Lane and others have placed scientific medicine on a firm basis.

THE GROWTH OF PREVENTIVE MEDICINE

Sanitary science, hygiene, or preventive medicine may claim to be one of the brightest spots in the history of the nineteenth century. Public hygiene was cultivated among the Egyptians, and in the Mosaic law it reached a remarkable organization. The personal hygiene of the Greeks was embraced in the saying, "The fair mind in the fair body," and the value of exercise and training was fully recognized. The Romans, too, in public and private hygiene, were our superiors in the matter of water supply and baths. But modern sanitary science has a much wider scope and is concerned with the causes of disease quite as much as with the conditions under which these diseases prevail. The foundations of the science were laid in the last century with Jenner's discovery of vaccination. Howard, too, had grasped the association of fever with overcrowding in the jails, while the possibility of the prevention of scurvy had been shown by Captain Cook and by Sir Gilbert Blaine.

Preventive medicine was a blundering, incomplete science until bacteriology opened unheard-of possibilities for the prevention of disease. Before discussing some of the victories of preventive medicine it will be well to take a brief survey of the growth of the following subject:

181

SCIENCE OF BACTERIOLOGY

From the brilliant overthrow by Pasteur, in 1861, and by Koch and Cohn, in 1876, of the theory of spontaneous generation, we may date its modern growth. Wrapped up in this theory of spontaneous generation, upon which speculation raged centuries before the invention of the microscope, lies the history of bacteriology.

The ancient Greek and Roman philosophers wrestled with the question, and very interesting views of the relation of germ life to disease are preserved to us in their manuscripts. With the invention of the microscope we can mark the first positive step towards the goal of to-day. A Jesuit priest, Kircher, in 1671, was the first to investigate putrefying meat, milk, and cheese with the crude microscope of his day, and left us indefinite remarks concerning "very minute living worms" found therein. Four years after Kircher a Dutch linen merchant, Antonius von Leeuwenhoek, by improving the lenses of the microscope, saw in rain-water, putrefying fluids, intestinal contents, and saliva, minute, moving, living particles, which he called "animalculæ." In medical circles of his day these observations aroused the keenest interest, and the theory that these "animalculæ" might be the cause of all disease was eagerly discussed. Pleincz, of Vienna, after much observation of various fluids, putrefying and otherwise, wrote in 1762 that it was his firm belief that the phenomena of diseases and the decomposition of animal fluids were wholly caused by these minute living things.

Notwithstanding such assertions, from his day on until Pasteur, Koch, and Cohn finally proved its misconceptions in 1876, the theory of spontaneous generation held the upper hand in all discussions upon the question.

The stimulus to research as to the causes of disease along the line of bacterial origin did not entirely cease to be felt, and the names of Pollender and Davaine are linked together in the first 182 undoubted discovery of micro-organisms in disease, when the cause of anthrax, a disease of cattle, was solved in 1863. Following closely upon Davaine's researches, the primary causes of wound infection were worked out, and to the efforts of the British surgeon Lister are due the great advances of modern surgery.

In rapid succession the presence of bacteria was clearly demonstrated in relapsing fever, leprosy, and typhoid fever; but far eclipsing all former discoveries, on account of the magnitude of the difficulties encountered and overcome, were the brilliant demonstrations of the cause of consumption and allied diseases, and that of Asiatic cholera, by Dr. Robert Koch in 1882 and in 1884 respectively.

From that time onward innumerable workers have satisfied the critical scientific world as to the causes of pneumonia, diphtheria, tetanus, influenza, and bubonic plague, besides many diseases of cattle, horses, sheep, and other animals and insects.

Having glanced hastily at the history of bacteriology, we may next consider some facts concerning the germs themselves. What are they? To the lay mind the words germ, microbe, bacterium, and bacillus often convey confused ideas of invisible, wriggling, worm-like creatures, enemies of mankind, ever on the watch to gain a stealthy entrance into our bodies, where they wreak harm and death. Scientifically considered, however, they are the smallest of living things yet known. They are not animals, but are members of the vegetable kingdom, and are possessed of definite yet varying shapes. They consist of a jelly-like substance called protoplasm, which is covered in and held in place by a well-formed membrane of a relatively hard and dense character, exactly similar in composition to the woody fibre of trees.

According to their shape the bacteria are divided into three chief groups, called respectively cocci, 183 bacilli, and spirilla. The cocci are spherical bodies and may exist singly or in pairs, in fours, in clusters, or in chains. In this group we find the smallest bacteria known, many of them not over 1-150,000 of an inch in diameter. The bacilli are rod-like bodies, varying much in size in different species and in members of the same species. They are larger than the cocci, measuring in length from 1-25,000 of an inch to 1-4000, and in breadth from 1-125,000 to 1-16,000 of an inch. Many varieties are possessed of organs of locomotion called flagella.

The spirilla resemble the bacilli, except that they are twisted into corkscrew shapes, or have gently undulating outlines. Upon an average they are much longer than the bacilli, one species being very long, measuring about 1-600 of an inch. As seen in the natural state bacteria are found to be colorless, but it is by the application of various aniline dyes that they are usually studied. These minute plants increase by a simple method of division into two equal parts, or by a more complex process of forming a seed—the so-called spore—which later on develops into the adult form. Under favorable conditions they are able to multiply at an enormous rate; for instance, it has been calculated that a bacillus dividing once every hour would at the end of twenty-four hours have increased to seventeen millions; and if the division continued at the same rate we should find at the end of the third day an incalculable number of billions, whose weight would be nearly seven thousand five hundred tons!

But, fortunately for our welfare, nature by various means renders the possibility of such a happening entirely beyond the slightest chance of realization, her greatest barrier being the lack of an adequate food supply.

The distribution in nature of bacteria is wellnigh universal, occurring as they do in the air we 184 breathe, the water and milk we drink, upon the exposed surfaces of man and animals, and in their intestinal tracts, and in the soil to a depth of about nine feet. But it has been noted that at very high altitudes and in glacier ice none exist, while in the Arctic regions and at sea far from land their numbers are very few.

The conditions governing their growth involve many complex problems, but a few of the chief factors concerned are moisture, air, food, temperature, and light. All bacteria must have moisture, else they die sooner or later, depending upon the hardness of the species, and none can multiply without it. A supply of air is by no means essential to all germs. To some it is absolutely necessary, and such germs are called aerobes. To others air is wholly detrimental, and they constitute the anaerobes, while to the majority of bacteria air supply is a matter of indifference, and in consequence they are grouped under the term facultative anaerobes.

The food supply of many consists of dead animal and vegetable materials, a few require living tissues, while a small number can exist wholly upon mineral salts, or even the nitrogen of the air. The lowest temperature at which some bacteria can multiply is the freezing-point of water, and the highest 170 degrees Fahrenheit. However, the average range of temperature suitable to the majority lies between 60 and 104 degrees Fahrenheit, 98 2-5 degrees Fahrenheit being the most suitable for the growth of disease-producing germs. Light, ordinarily diffused daylight, or its absence, is a matter of no moment to most germs, whereas direct sunlight is a destroyer of all bacteria.

The study of the life histories of these diminutive plants excites the wonder of those who make observations upon them. It is truly marvellous to know that these bacteria can accomplish in their short lives of possibly a few hours or days feats which would baffle the cleverest of chemists if given years 185 of a lifetime to work upon. They give to the farmer the good quality of his crops, to the dairyman superior butter and cheese; they assist in large measure in freeing our rivers and lakes from harmful pollutions. Here it should be strongly emphasized that those bacteria which cause disease are only of a few species, all others contributing to our welfare in countless ways.

Quite as astonishing is the discovery that within the root-knobs of pease and beans live bacteria which by splitting up mineral salts containing nitrogen, and by absorbing nitrogen from the air, give it over to the plant so that it is enabled to grow luxuriantly, whereas, without their presence, the tiller of the soil might fertilize the ground in vain. It is quite possible that not alone pease and beans, but all grasses and plants and trees depend upon the presence of such germs for their very existence, which in turn supply man and animals with their means of existence. Hence we see that these nitrifying bacteria, as they are called, if swept out of existence, would be the cause of cessation of all life upon the globe. And arguing backward, one prominent authority states it as his belief that the first of all life on this earth were those lowly forms of plants which only required the nitrogen of air or salts to enable them to multiply.

Limiting observation now to the sphere of medicine, it will be readily perceived that the presence of bacterial life in a causative relation to disease is an object of paramount regard. The following paragraphs will briefly treat of the diseases associated with micro-organisms and the common modes of infection in each, the chain of events subsequent to an infection, and the possibilities of protection or cure by means of substances elaborated in the body of an individual or animal recently recovered from an infectious disease:

Anthrax.—A disease chiefly of cattle and sheep, occasionally of man, is caused by the *Bacillus anthracis*, discovered in 1849–50 by Pollender and Davaine. It enters the body through abrasions of the skin, by inhalation of the spores, or seeds, into the lungs, or by swallowing infected material. 186

Leprosy.—This disease is caused by a bacillus known as *Bacillus leprae*, which was discovered by Hansen in 1879. It is doubtful if it has been grown outside the body. It is supposed to enter by abrasions of the skin, but it is very feebly contagious, notwithstanding popular ideas as to its supposedly highly contagious nature.

Tuberculosis.—All forms of this disease, among which is ordinary consumption, are caused by a bacillus closely resembling that of leprosy. It was discovered by Koch in 1880–82, and named *Bacillus tuberculosis*. The ways of infection are by inhaling the dried sputum of consumptives, drinking infected cow’s milk, or eating infected meat.

Typhoid Fever.—A disease of human beings only. Eberth in 1880 discovered the germ causing it and called it *Bacillus typhosus*. It gains entrance to our bodies chiefly in the milk and water we drink, which comes from infected sources; a rarer method is by inhalation of infected air.

Diphtheria.—A disease of human beings chiefly. It is caused by a bacillus which was described in 1883–84 by Klebs and Loeffler, and is known as *Bacillus diphtheriae*, or Klebs-Loeffler bacillus. Its mode of entry is by inhaling infected air, or by drinking or eating infected milk or food.

Cholera.—This disease is peculiar to human beings. Its native home is on the banks of the river Ganges in India, where Koch in 1884 was able to isolate its causative spirillum. Man is infected by drinking contaminated water or by contact.

Lockjaw, or Tetanus.—Afflicts man, horses, and dogs. The *Bacillus tetani* is the most deadly of all known bacteria. It enters the body by wounds. It was discovered in 1884 by Nicolaier. 187

Influenza, or the Grip.—Caused by one of the smallest-known bacilli; discovered in 1892 by Canon and Pfeiffer. Infection spreads by the scattering about by air-currents of the dried nasal and bronchial secretion of those suffering from the disease, and its portal of entry is by the nose and bronchial tubes.

Pneumonia.—Caused by a coccus which grows in pairs and small chains. It enters the body by means of the respiratory tract. It is present in the saliva of twenty per cent. of healthy persons. Proved by Frankel in 1886 to be the cause of this disease.

Bubonic Plague.—In 1894 Kitasato and Yersin isolated a small bacillus in a large number of cases and proved it to be the cause. It enters the body by means of wounds of the skin, and through bites of fleas from infected rats, which are said to be one of the chief factors in spreading this dread malady.

Yellow Fever.—The cause of this disease is still under discussion.

Such are a few of the infectious diseases which we can readily attribute to the presence of definite micro-organisms in respective cases. But strange as it may seem, the most typical of all infectious diseases, small-pox, scarlet fever, measles, and hydrophobia, have as yet not yielded up their secrets. This is possibly due to the minute size of the micro-organisms concerned, which make it beyond the power of the best microscope to demonstrate them. In this connection it has recently been shown by Roux and Nocard that in the case of the disease known as pleuro-pneumonia of cattle the causative agent is so very small as just to be barely visible. Again, it is quite possible that these diseases may be caused by living things we know nothing about, which may be quite dissimilar from the bacteria. 188

INFECTION—ITS PROCESSES AND RESULTS

In the foregoing list of diseases associated with specific bacteria, attention has been drawn to the common modes of infection, or, as they are technically called, “portals of entry,” and it now remains to touch upon the main factors, processes, and results following upon the entry into the body of such disease-producing microbes.

It is a well-known fact that the normal blood has of itself to a considerable extent the power of killing germs which may wander into it through various channels. Likewise the tissue cells of the body in general show similar action depending upon the different cell groups, state of health, general robustness, and period of life. The germ-killing power varies in different individuals, though each may be quite healthy. Considered as a whole, this power possessed by the body against germs is known as “general resistance.” And when by any means this power of resistance is lost or diminished, we run grave risks of incurring disease.

Granted a case of infection, let us now trace up briefly what occurs. Between the period when the bacteria gain a lodgment and that in which the disease assumes a noticeable form, the patient simply feels out of sorts. It is during this stage that the blood and tissues are deeply engaged in the attempt to repel the attacks of the invading microbes.

With varying speed the germs multiply throughout the body generally, or may be at first localized, or even, as in lockjaw, remain localized throughout the entire disease. Multiplying in the tissues, they generate in increasing amounts their noxious poisons, which soon cause profound changes throughout the body; the patient becomes decidedly ill, and shows now the signs of an unmistakable infection. 189

Does the body now give up the fight entirely? No; on the contrary, the white blood-cells, the wandering cells, and the cells of the tissues most affected still carry on an unequal fight. From the lymphatic glands and spleen, armies of white cells rush to the fray and attempt to eat up and destroy the foe, but possibly in vain; the disease runs its course, to end either in death or recovery.

How, then, in cases of recovery, are the microbes finally overcome?

This question involves many complex processes which at present are by no means thoroughly understood, but we will concern ourselves with the simple principles.

It has been previously mentioned that once the bacteria get a good foothold the body is subjected to the action of generated poisons, which are known as toxins. They give rise to such symptoms as loss of appetite, headache, fever, pains and aches, and even a state of stupor or unconsciousness. In addition to the active warfare of the white blood-cells, groups of cells throughout the body, after recovering from the first rude shock of the toxins, begin to tolerate their presence, then effect a change in the chemical constitution of the toxins, and finally elaborate substances which antagonize the toxins and destroy their action altogether, thus lending aid to the warrior cells, which at last overcome the invading microbes. Recovery is brought about, and a more or less permanent degree of immunity against the special form of disease ensues.

Now if we could use these antagonizing substances, or, as they are called, antitoxins, upon other men or animals sick with a similar disease, would their bodies be at once strengthened to resist and finally overcome the disease? Yes, in a certain majority of cases they would, and this is exactly what scientific observers have noted, worked out, and have successfully applied. A new art in the healing of 190
disease, which is spoken of broadly as serum-therapy, or medication by curative or protective serums, has thus been discovered.

The first observers in this new field were Pasteur and Raynaud in France in 1877–78, and Salmon and Smith in this country in 1886. Raynaud, by injecting serum from a calf which had had an attack of cow-pox, prevented the appearance of the disease in a calf freshly inoculated with the virulent material of the disease. Pasteur, by using feebly infective germs of fowl cholera, conferred immunity upon healthy fowls against the disease, and was able to cure those which were ill. Salmon and Smith injected small and repeated amounts of the elaborated toxins or poisons of the bacillus of hog cholera into healthy swine, and were able to confer immunity upon them.

However, it was not until Behring in 1892 announced his discovery of an antitoxin serum for diphtheria, along with an undisputed proof of its value in treatment, that the attention of the scientific world was finally aroused and stimulated to the appreciation of the great possibilities of serum-therapy.

Strange as it may seem, much opposition arose to this new method of treatment, not alone from the lay portions of the community, but even from the ranks of the medical profession itself. This opposition was due in part to misconceptions of the principles involved in the new doctrine, and in part to the falsely philanthropic prejudices of the pseudo-scientific sections of both parties. But by the persevering work of the enthusiastic believers in serum-therapy, positive conviction has now replaced misconception and prejudice in the minds of the majority of its former opponents.

The accumulation of statistical evidence, even where all allowance is made for doubtful methods of compilation, shows that the aggregate mortality of diphtheria has been reduced fully fifty per cent. 191
since the introduction of antitoxic treatment by Behring in 1892.

Since the method of preparation of the commercial diphtheria antitoxin illustrates the general principles involved in the search for the production of curative or protective serums for infectious diseases in general, a summary of the steps in its manufacture will now be given.

A race of diphtheria bacilli, which has been found to yield a poison of great virulence in alkaline beef broth, is grown for a week or ten days in this medium. The toxin is then separated and its virulence exactly determined. It is preserved in sterile receptacles for immediate or future use. The next step is the inoculation of a suitable animal with the toxin. Of all animals the horse has been found to meet nearly every requirement. Such an animal, in a state of perfect health, receives an injection of twenty cubic centimetres of toxin, along with ten or fifteen of standard antitoxin, beneath the skin of the neck or fore-quarters, upon three separate occasions at intervals of five days. After this it receives increasing doses of toxin, alone, at intervals of six to eight days, until, at the end of two months, it is able to stand with little discomfort doses of such strength that if given in the first stage these doses would have quickly caused death.

At this period the horse is bled to a small extent, and its serum tested to ascertain if prospects are good for the production by the animal of a high grade of antitoxin. If satisfactory progress has been made, the injections are continued for another month, when, as a rule, the maximal degree of antitoxic power in the serum will have been attained.

The horse is now bled to the proper extent, the blood being received in a sterile jar and placed in an ice-box. Here it coagulates, and the serum separates from it. When the separation of clot and serum 192
is complete, the latter is drawn off, taken to the laboratory, and standardized. This being finished, an antiseptic fluid is added to preserve the serum from decomposition. It is then bottled, labelled, and sent out for use.

In similar fashion tetanus antitoxin is prepared; and quite recently Calmette has produced an antitoxic serum for use in snake bite, by injecting horses with minute increasing doses of snake venom. His experiments have given some remarkable results, not only in laboratory work, but also in cases of actual snake bite occurring in man. Thus bacteriological scientists, after years of laborious work, in the face of much criticism and severe denunciation, may confidently announce that they have in their possession a magic key to one of nature's secret doors. The lock has been turned. The door stands partly open, and we are permitted a glimpse of the future possibilities to be attained in the great fight against disease.

PREVENTIVE MEDICINE

The following are some of the diseases which have been remarkably controlled through preventive medicine:

Small-pox.—While not a scourge of the first rank, like the plague or cholera, at the outset of the century variola was one of the most prevalent and dreaded of all diseases. Few reached adult life without an attack. To-day, though outbreaks still occur, it is a disease thoroughly controlled by vaccination. The protective power of the inoculated cow-pox is not a fixed and constant quantity. The protection may be for life, or it may last only for a year or two. The all-important fact is this: That efficiently vaccinated persons may be exposed with impunity, and among large bodies of men (*e.g.*, the 193 German army), in which revaccination is practised, small-pox is unknown. Of one hundred vaccinated persons exposed to small-pox, possibly one might take the disease in a mild form; of one hundred unvaccinated persons so exposed, one alone might escape—from twenty-five to thirty would die. To be efficient, vaccination must be carried out systematically, and if all the inhabitants of this country were revaccinated at intervals small-pox would disappear (as it has from the German army), and the necessity for vaccination would cease. The difficulty arises from the constant presence of an unvaccinated remnant, by which the disease is kept alive. The Montreal experience in 1885 is an object-lesson never to be forgotten.

For eight or ten years vaccination had been neglected, particularly among the French-Canadians. On February 28, 1885, a Pullman car conductor, who came from Chicago, where the disease had been slightly prevalent, was admitted into the Hôtel Dieu. Isolation was not carried out, and on the 1st of April a servant in the hospital died of small-pox. Following her death the authorities of the hospital sent to their homes all patients who presented no symptoms of the disease. Like fire in dry grass the contagion spread, and within nine months there died of small-pox three thousand one hundred and sixty-four persons. It ruined the trade of the city for the winter, and cost millions of dollars. There are no reasonable objections to vaccination, which is a simple process, by which a mild and harmless disease is introduced. The use of the animal vaccine does away with the possibility of introduction of other disorders, such as syphilis.

Typhus Fever.—Until the middle of the present century this disease prevailed widely in most of the large cities, particularly in Europe, and also in jails, ships, hospitals, and camps. It was more 194 widely spread than typhoid fever and much more fatal. Murchison remarks of it that a complete history of its ravages would be the history of Europe during the past three centuries and a half. Not one of the acute infections seems to have been more dependent upon filth and unsanitary conditions. With the gradual introduction of drainage and a good water supply, and the relief of overcrowding, the disease has almost entirely disappeared, and is rarely mentioned now in the bills of mortality, except in a few of the larger and more unsanitary cities. The following figures illustrate what has been done in England within sixty years: In 1838 in England twelve hundred and twenty-eight persons died of fever (typhus and typhoid) per million of living. Twenty years later the figures were reduced to nine hundred and eighteen; in 1878 to three hundred and six of typhoid and to thirty-six of typhus fever. In 1892 only one hundred and thirty-seven died of typhoid fever and only three of typhus per million living!

Typhoid Fever.—While preventive medicine can claim a great victory in this disease also, it is less brilliant, since the conditions which favor its prevalence are not those specially relating to overcrowding as much as to imperfect water supply and the contamination of certain essential foods, as milk. It has been repeatedly demonstrated that, with a pure water supply and perfect drainage, typhoid fever almost disappears from a city. In Vienna, after the introduction of good water, the rate of mortality from typhoid fever fell from twelve per ten thousand of the inhabitants to about one. In Munich the fall was still more remarkable; from above twenty-nine per ten thousand inhabitants in 1857 it fell to about one per ten thousand in 1887. That typhoid fever in this country is still a very prevalent disease depends mainly upon two facts: First, not only is the typhoid bacillus very resistant, [195] but it may remain for a long time in the body of a person after recovery from typhoid fever, and such persons, in apparent good health, may be a source of contamination. With many of the conditions favoring the persistence and growth of the bacillus outside the body we are not yet familiar. The experience in the Spanish-American War illustrates how dangerous is the concentration together of large numbers of individuals. But, second, the essential factor in the widespread prevalence of typhoid fever in the United States, particularly in country districts, is the absence of anything like efficient rural sanitation. Many counties have yet to learn the alphabet of sanitation. The chief danger results from the impure water supplies of the smaller towns, the local house epidemics due to infected wells, and the milk outbreaks due to the infection of dairy farms.

The importance of scrupulously guarding the sources of supply was never better illustrated than in the well-known and oft-quoted epidemic in Plymouth, Pennsylvania. The town, with a population of eight thousand, was in part supplied with drinking-water from a reservoir fed by a mountain-stream. During January, February, and March, in a cottage by the side of and at a distance of from sixty to eighty feet from this stream, a man was ill with typhoid fever. The attendants were in the habit at night of throwing out the evacuations on the ground towards the stream. During these months the ground was frozen and covered with snow. In the latter part of March and early in April there was considerable rainfall and a thaw, in which a large part of the three months' accumulation of discharges was washed into the brook not sixty feet distant. At the very time of this thaw the patient had numerous and copious discharges. About the 10th of April cases of typhoid fever broke out in the town, appearing for a time at the rate of fifty a day. In all about twelve hundred were attacked. An [196] immense majority of the cases were in the part of the town which received water from the infected reservoir.

The use of boiled water and of ice made from distilled water, the systematic inspection of dairies, the scrupulous supervision of the sources from which the water is obtained, an efficient system of sewage removal, and, above all, the most scrupulous care on the part of physicians and of nurses in the disinfection of the discharges of typhoid fever patients—these are the factors necessary to reduce to a minimum the incidence of typhoid fever.

Cholera.—One of the great scourges of the present century made inroads into Europe and America from India, its native home. We have, however, found out the germ, found out the conditions under which it lives, and it is not likely that it will ever again gain a foothold in this country or Great Britain. Since the last epidemic, 1873, the disease, though brought to this country on several occasions, has always been held in check at the port of entry. It is communicated almost entirely through infected water, and the virulence of an epidemic in any city is in direct proportion to the imperfection of the water supply. This was shown in a remarkable way in the Hamburg epidemic of 1892. In Altona, which had a filtration plant, there were only five hundred and sixteen cases, many of them refugees from Hamburg. Hamburg, where the unfiltered water of the Elbe was used, had some eighteen thousand cases, with nearly eight thousand deaths.

Yellow Fever.—The cause of this disease is still under discussion. It has an interest to us in this country from its continued prevalence in Cuba, and from the fact that at intervals it makes inroads into the Southern States, causing serious commercial loss. The history of the disease in the other West India islands, particularly Jamaica, indicates the steps which must be taken for its prevention. Formerly [197] yellow fever was as fatal a scourge in them as it is to-day in Cuba. By an efficient system of sanitation it has been abolished. The same can be done (and will be done) in Cuba within a few years. General Wood has already pointed out the way in the cleansing of Santiago.

The Plague.—One of the most remarkable facts in connection with modern epidemics has been the revival of the bubonic plague, the most dreaded of all the great infections. During the present century the disease in Europe has been confined almost exclusively to Turkey and Southern Europe. Since 1894, when it appeared at Hong-Kong, it has gradually spread, and there have been outbreaks of terrible severity in India. It has extended to certain of the Mediterranean ports, and during the past summer it reached Glasgow, where there has been a small outbreak. On this hemisphere there have been small outbreaks in certain of the South American ports, cases have been brought to New York, and there have been to November 1st twenty-one cases among the Chinese in San Francisco. Judging from the readiness with which it has been checked and limited in Australia, and in particular the facility with which the recent outbreak in Glasgow has been stamped out, there is very little risk that plague will ever assume the proportions which gave to it its terrible reputation as the "black death" of the Middle Ages. As I have already mentioned, the germ is known, and prophylactic inoculations have been made on a large scale in India, with a certain measure of success.

Tuberculosis.—In all communities the *white plague*, as Oliver Wendell Holmes calls it, takes the first rank as a killing disease. It has been estimated that of it one hundred and twenty thousand people die yearly in this country. In all mortality bills tuberculosis of the lungs, or consumption, heads the list, and when to this is added tuberculosis of the other organs, the number swells to such an extent that this 198
disease equals in fatality all the other acute infective diseases combined, if we leave out pneumonia. Less than twenty years ago we knew little or nothing of the cause of the disease. It was believed to be largely hereditary. Koch discovered the germ, and with this have come the possibilities of limiting its ravages.

The following points with reference to it may be stated: In a few very rare instances the disease is transmitted from parent to child. In a large proportion of all cases the disease is "caught." The germs are widely distributed through the sputum, which, when dry, becomes dust, and is blown about in all directions. Tubercle bacilli have been found in the dust of streets, houses, hospital wards, and much-frequented places. A single individual may discharge from the lungs countless myriads of germs in the twenty-four hours. Dr. Nuttall estimated from a patient in the Johns Hopkins Hospital, who had only moderately advanced consumption, that from one and a half to four and a third billions of germs were thrown off in the twenty-four hours. The consumptive, as has been well stated, is almost harmless, and only becomes harmful through bad habits. The germs are contained in the sputum, which, when dry, is widely scattered in the form of dust, and constitutes the great medium for the transmission of the disease. If expectorated into a handkerchief, the sputum dries quickly, particularly if it is put into the pocket or under the pillow. The beard or mustache of a consumptive is smeared with the germs. Even in the most careful the hands are apt to be soiled with the germs, and in those who are dirty and careless the furniture and materials which they handle readily become infected. Where the dirty habit prevails of spitting on the floor, a room, or the entire house, may contain numbers of germs. In the 199
majority of all cases the infection in tuberculosis is by inhalation. This is shown by the frequency with which the disease is met in the lungs, and the great prevalence of tuberculosis in institutions in which the residents are restricted in the matter of fresh air and a free, open life. The disease prevails specially in cloisters, in jails, and in asylums. Infection through milk is also possible; it is doubtful whether the disease is transmitted through meat. So widespread are the germs that post-mortem examination has shown that a very large number of persons show slight signs of the disease who have never during life presented any symptoms; in fact, some recent investigations would indicate that a very large proportion of all persons at the age of forty have somewhere in their bodies slight tuberculous lesions. This shows the importance of the individual predisposition, upon which the older writers laid so much stress, and the importance of maintaining the nutrition at its maximum.

One of the most remarkable features of modern protective medicine is the widespread interest that has been aroused in the crusade against tuberculosis. What has already been accomplished warrants the belief that the hopes of even the most enthusiastic may be realized. A positive decline in the prevalence of the disease has been shown in many of the larger cities during the past ten years. In

Massachusetts, which has been a hot-bed of tuberculosis for many years, the death-rate has fallen from forty-two per ten thousand inhabitants in 1853 to twenty-one and eight-tenths per ten thousand inhabitants in 1895. In the city of Glasgow, in which the records have been very carefully kept, there has been an extraordinary fall in the death-rate from tuberculosis, and the recent statistics of New York City show, too, a similar remarkable diminution.

In fighting the disease our chief weapons are: First, education of the public, particularly of the 200
poorer classes, who do not fully appreciate the chief danger in the disease. Secondly, the compulsory notification and registration of all cases of tuberculosis. The importance of this relates chiefly to the very poor and improvident, from whom, after all, comes the greatest danger, and who should be under constant surveillance in order that these dangers may be reduced to a minimum. Thirdly, the foundation in suitable localities by the city and by the State of sanatoria for the treatment of early cases of the disease. Fourthly, provision for the chronic, incurable cases in special hospitals.

Diphtheria.—Since the discovery of the germ of this disease and our knowledge of the conditions of its transmission, and the discovery of the antitoxin, there has been a great reduction in its prevalence and an equally remarkable reduction in the mortality. The more careful isolation of the sick, the thorough disinfection of the clothing, the rigid scrutiny of the milder cases of throat disorder, a more stringent surveillance in the period of convalescence, and the routine examination of the throats of school-children—these are the essential measures by which the prevalence of the disease has been very markedly diminished. The great danger is in the mild cases, in which the disease has perhaps not been suspected, and in which the child may be walking about and even going to school. Such patients are often a source of widespread infection. The careful attention given by mothers to the teeth and mouth of children is also an important factor. In children with recurring attacks of tonsillitis, in whom the tonsils are enlarged, the organs should be removed. Through these measures the incidence of the disease has been very greatly reduced.

Pneumonia.—While there has been a remarkable diminution in the prevalence of a large number
of all the acute infections, one disease not only holds its own, but seems even to have increased in its 201
virulence. In the mortality bills, pneumonia is an easy second to tuberculosis. It attacks particularly the intemperate, the feeble, and the old, though every year a large number of robust, healthy individuals succumb. So frequent is pneumonia at advanced periods of life that to die of it has been said to be the natural end of old men in this country. In many ways, too, it is a satisfactory disease, if one may use such an expression. It is not associated with much pain, except at the onset, the battle is brief and short, and a great many old persons succumb to it easily and peacefully.

We know the cause of the disease; we know only too well its symptoms, but the enormous fatality (from twenty to twenty-five per cent.) speaks only too plainly of the futility of our means of cure, and yet in no disease has there been so great a revolution in treatment. The patient is no longer drenched to death with drugs, or bled to a point where the resisting powers of nature are exhausted. We are not without hope, too, that in the future an antidote may be found to the toxins of the disease, and of late there have been introduced several measures of great value in supporting the weakness of the heart, a special danger in the old and debilitated.

Hydrophobia.—Rabies, a remarkable, and in certain countries a widespread, disease of animals, when transmitted to a man by the bite of rabid dogs, wolves, etc., is known as hydrophobia. The specific germ is unknown, but by a series of brilliant observations Pasteur showed (1) that the poison has certain fixed and peculiar properties in connection with the nervous system; (2) that susceptible animals could be rendered refractory to the disease, or incapable of taking it, by a certain method of
inoculation; and (3) that an animal unprotected and inoculated with a dose of the virus sufficient to 202
cause the disease may, by the injection of proper anti-rabic treatment, escape. Supported by these facts, Pasteur began a system of treatment of hydrophobia in man, and a special institute was founded in Paris for the purpose. When carried out promptly the treatment is successful in an immense majority of all cases, and the mortality in persons bitten by animals proved to be rabid, who have subsequently had the anti-rabic treatment, has been reduced to less than one-half per cent. The disease may be stamped out in dogs by careful quarantine of suspected animals, and by a thoroughly carried out muzzling order.

Malaria.—Among the most remarkable of modern discoveries is the cause of malarial fever, one of the great maladies of the world, and a prime obstacle to the settlement of Europeans in tropical regions. Until 1880 the cause was quite obscure. It was known that the disease prevailed chiefly in marshy districts, in the autumn, and that the danger of infection was greatest in the evening and at night, and that it was not directly contagious. In 1880 a French army surgeon, Laveran, discovered in the red blood-corpuscles small bodies which have proved to be the specific germ of the disease. They are not bacteria, but little animal bodies resembling the amœba—tiny little portions of protoplasm. The parasite in its earliest form is a small, clear, ring-shaped body inside the red blood-corpuscle, upon which it feeds, gradually increasing in size and forming within itself blackish grains out of the coloring matter of the corpuscle. When the little parasite reaches a certain size it begins to divide or multiply, and an enormous number of these breaking up at the same time give off poison in the blood, which causes the paroxysms of fever. During what is known as the chill, in the intermittent fever, for example, one can always find these dividing parasites. Several different forms of the parasites have been found, corresponding to different varieties of malaria. Parasites of a very similar nature exist 203
abundantly in birds. Ross, an army surgeon in India, found that the spread of this parasite from bird to bird was effected through the intervention of the mosquito. The parasites reach maturity in certain cells of the coats of the stomach of these insects, and develop into peculiar thread-like bodies, many of which ultimately reach the salivary glands, from which, as the insect bites, they pass with the secretion of the glands into the wound. From this as a basis, numerous observers have worked out the relation of the mosquito to malaria in the human subject.

Briefly stated, the disease is transmitted chiefly by certain varieties of the mosquito, particularly the *Anopheles*. The ordinary *Culex*, which is present chiefly in the Northern States, does not convey the disease. The *Anopheles* sucks the blood from a person infected with malaria, takes in a certain number of parasites, which undergo development in the body of the insect, the final outcome of which is numerous small, thread-like structures, which are found in numbers in the salivary glands. From this point, when the mosquito bites another individual, they pass into his blood, infect the system, and in this way the disease is transmitted. Two very striking experiments may be mentioned. The Italian observers have repeatedly shown that *Anopheles* which have sucked blood from patients suffering from malaria, when sent to a non-malarial region, and there allowed to bite perfectly healthy persons, have transmitted the disease. But a very crucial experiment was made a short time ago. Mosquitoes which had bitten malarial patients in Italy were sent to London and there allowed to bite Mr. Manson, son of Dr. Manson, who really suggested the mosquito theory of malaria. This gentleman had not lived out of England, and there is no acute malaria in London. He had been a perfectly healthy, strong man. 204
In a few days following the bites of the infected mosquitoes he had a typical attack of malarial fever.

The other experiment, though of a different character, is quite as convincing. In certain regions about Rome, in the Campania, malaria is so prevalent that in the autumn almost every one in the district is attacked, particularly if he is a new-comer. Dr. Sambron and a friend lived in this district from the 1st of June to the 1st of September, 1900. The test was whether they could live in this exceedingly dangerous climate for the three months without catching malaria, if they used stringent precautions against the bites of mosquitoes. For this purpose the hut in which they lived was thoroughly wired, and they slept with the greatest care under netting. Both of these gentlemen at the end of the period had escaped the disease.

The importance of these studies cannot be overestimated. They explain the relation of malaria to marshy districts, the seasonal incidence of the disease, the nocturnal infection, and many other hitherto obscure problems. More important still, they point out clearly the way by which malaria may be prevented: First, the recognition that any individual with malaria is a source of danger in a community, so that he must be thoroughly treated with quinine; secondly, the importance of the draining of marshy districts and ponds in which mosquitoes breed; and, thirdly, that even in the most infected regions persons may escape the disease by living in thoroughly protected houses, in this way escaping the bites of mosquitoes.

Venereal Diseases.—These continue to embarrass the social economist and to perplex and distress the profession. The misery and ill-health which they cause are incalculable, and the pity of it is that the cross is not always borne by the offender, but innocent women and children share the penalties. The gonorrhœal infection, so common, and often so little heeded, is a cause of much disease in parts other than those first affected. Syphilis claims its victims in every rank of life, at every age, and in all countries. We now treat it more thoroughly, but all attempts to check its ravages have been fruitless. Physicians have two important duties: the incessant preaching of continence to young men, and scrupulous care, in every case, that the disease may not be a source of infection to others, and that by thorough treatment the patient may be saved from the serious late nervous manifestations. We can also urge that in the interests of public health venereal diseases, like other infections, shall be subject to supervision by the State. The opposition to measures tending to the restriction of these diseases is most natural: on the one hand, from women, who feel that it is an aggravation of a shocking injustice and wrong to their sex; on the other, from those who feel the moral guilt in a legal recognition of the evil. It is appalling to contemplate the frightful train of miseries which a single diseased woman may entail, not alone on her associates, but on scores of the innocent—whose bitter cry should make the opponents of legislation feel that any measures of restriction, any measures of registration, would be preferable to the present disgraceful condition, which makes of some Christian cities open brothels and allows the purest homes to be invaded by the most loathsome of all diseases. 205

Leprosy.—Since the discovery of the germ of this terrible disease systematic efforts have been made to improve the state of its victims and to promote the study of the conditions under which the disease prevails. The English Leprosy Commission has done good work in calling attention to the widespread prevalence of the disease in India and in the East. In this country leprosy has been introduced into San Francisco by the Chinese, and into the Northwestern States by the Norwegians, 206 and there are foci of the disease in the Southern States, particularly Louisiana, and in the province of New Brunswick. The problem has an additional interest since the annexation of Hawaii and the Philippine Islands, in both of which places leprosy prevails extensively. By systematic measures of inspection and the segregation of affected individuals the disease can readily be held in check. It is not likely ever to increase among native Americans, or again gain such a foothold as it had in the Middle Ages.

Puerperal Fever.—Perhaps one of the most striking of all victories of preventive medicine has been the almost total abolition of so-called child-bed fever from the maternity hospitals and from private practice. In many institutions the mortality after child-birth was five or six per cent., indeed sometimes as high as ten per cent., whereas to-day, owing entirely to proper antiseptic precautions, the mortality has fallen to three-tenths to four-tenths per cent. The recognition of the contagiousness of puerperal fever was the most valuable contribution to medical science made by Oliver Wendell Holmes. There had been previous suggestions by several writers, but his essay on the "Contagiousness of Puerperal Fever," published in 1843, was the first strong, clear, logical statement of the case. Semmelweis, a few years later, added the weight of a large practical experience to the side of the contagiousness, but the full recognition of the causes of the disease was not reached until the recent antiseptic views had been put into practical effect.

THE NEW DISPENSATION IN TREATMENT

The century has witnessed a revolution in the treatment of disease, and the growth of a new school of medicine. The old schools—regular and homœopathic—put their trust in drugs, to give which was 207 the alpha and the omega of their practice. For every symptom there were a score or more of medicines —vile, nauseous compounds in one case; bland, harmless dilutions in the other. The new school has a firm faith in a few good, well-tried drugs, little or none in the great mass of medicines still in general use. Imperative drugging—the ordering of medicine in any and every malady—is no longer regarded as the chief function of the doctor. Naturally, when the entire conception of the disease was changed, there came a corresponding change in our therapeutics. In no respect is this more strikingly shown than in our present treatment of fever—say, of the common typhoid fever. During the first quarter of the century the patients were bled, blistered, purged and vomited, and dosed with mercury, antimony, and other compounds to meet special symptoms. During the second quarter, the same, with variations in different countries. After 1850 bleeding became less frequent, and the experiments of the Paris and Vienna schools began to shake the belief in the control of fever by drugs. During the last quarter sensible doctors have reached the conclusion that typhoid fever is not a disease to be treated with medicines, but that in a large proportion of all cases diet, nursing, and bathing meet the indications. There is active, systematic, careful, watchful treatment, but not with drugs. The public has not yet been fully educated to this point, and medicines have sometimes to be ordered for the sake of the friends, and it must be confessed that there are still in the ranks *antiques* who would insist on a dose of some kind every few hours.

The battle against poly-pharmacy, or the use of a large number of drugs (of the action of which we know little, yet we put them into bodies of the action of which we know less), has not been fought to a finish. There have been two contributing factors on the side of progress—the remarkable growth of the 208
skeptical spirit fostered by Paris, Vienna, and Boston physicians, and, above all, the valuable lesson of homœopathy, the infinitesimals of which certainly could not do harm, and quite as certainly could not do good; yet nobody has ever claimed that the mortality among homœopathic practitioners was greater than among those of the regular school. A new school of practitioners has arisen which cares nothing for homœopathy and less for so-called allopathy. It seeks to study, rationally and scientifically, the action of drugs, old and new. It is more concerned that a physician shall know how to apply the few great medicines which all have to use, such as quinine, iron, mercury, iodide of potassium, opium, and digitalis, rather than a multiplicity of remedies the action of which is extremely doubtful.

The growth of scientific pharmacology, by which we now have many active principles instead of crude drugs, and the discovery of the art of making medicines palatable, have been of enormous aid in rational practice. There is no limit to the possibility of help from the scientific investigation of the properties and action of drugs. At any day the new chemistry may give to us remedies of extraordinary potency and of as much usefulness as cocaine. There is no reason why we should not even in the vegetable world find for certain diseases specifics of virtue fully equal to that of quinine in the malarial fevers.

One of the most striking characteristics of the modern treatment of disease is the return to what used to be called the natural methods—diet, exercise, bathing, and massage. There probably never has been a period in the history of the profession when the value of *diet* in the prevention and the cure of disease was more fully recognized. Dyspepsia, the besetting malady of this country, is largely due to improper diet, imperfectly prepared and too hastily eaten. One of the great lessons to be learned is that 209
the preservation of health depends in great part upon food well cooked and carefully eaten. A common cause of ruined digestion, particularly in young girls, is the eating of sweets between meals and the drinking of the abominations dispensed in the chemists' shops in the form of ice-cream sodas, etc. Another frequent cause of ruined digestion in business men is the hurried meal at the lunch-counter. And a third factor, most important of all, illustrates the old maxim, that more people are killed by over eating and drinking than by the sword. Sensible people have begun to realize that alcoholic excesses lead inevitably to impaired health. A man may take four or five drinks of whiskey a day, or even more, and thinks perhaps that he transacts his business better with that amount of stimulant; but it only too frequently happens that early in the fifth decade, just as business or political success is assured, Bacchus hands in heavy bills for payment, in the form of serious disease of the arteries or of the liver, or there is a general breakdown. With the introduction of light beer there has been not only less intemperance, but a reduction in the number of the cases of organic disease of the heart, liver, and stomach caused by alcohol. While temperance in the matter of alcoholic drinks is becoming a characteristic feature of Americans, intemperance in the quantity of food taken is almost the rule. Adults eat far too much, and physicians are beginning to recognize that the early degenerations, particularly of the arteries and of the kidneys, leading to Bright's disease, which were formerly attributed to alcohol, are due in large part to too much food.

Nursing.—Perhaps in no particular does nineteenth-century practice differ from that of the preceding centuries more than in the greater attention which is given to the personal comfort of the patient and to all the accessories comprised in the art of nursing. The physician has in the trained nurse 210 an assistant who carries out his directions with a watchful care, and who is on the lookout for danger-signals, and with accurate notes enables him to estimate the progress of a critical case from hour to hour. The intelligent, devoted women who have adopted the profession of nursing, are not only in their ministrations a public benefaction, but they have lightened the anxieties which form so large a part of the load of the busy doctor.

Massage and Hydrotherapy have taken their places as most important measures of relief in many chronic conditions, and the latter has been almost universally adopted as the only safe means of combating the high temperatures of the acute fevers.

Within the past quarter of a century the value of *exercise* in the education of the young has become recognized. The increase in the means of taking wholesome out-of-door exercise is remarkable, and should show in a few years an influence in the reduction of the nervous troubles in young persons. The prophylactic benefit of systematic exercise, taken in moderation by persons of middle age, is very great. Golf and the bicycle have in the past few years materially lowered the average incomes of the doctors in this country as derived from persons under forty. From the senile contingent—those above this age—the average income has for a time been raised by these exercises, as a large number of persons have been injured by taking up sports which may be vigorously pursued with safety only by those with young arteries.

Of three departures in the art of healing, brief mention may be made. The use of the extracts of certain organs (or of the organs themselves) in disease is as old as the days of the Romans, but an extraordinary impetus has been given to the subject by the discovery of the curative powers of the 211
extract of the thyroid gland in the diseases known as cretinism and myxœdema. The brilliancy of the results in these diseases has had no parallel in the history of modern medicine, but it cannot be said that in the use of the extracts of other organs for disease the results have fulfilled the sanguine expectations of many. There was not, in the first place, the same physiological basis, and practitioners have used these extracts too indiscriminately and without sufficient knowledge of the subject.

Secondly, as I have already mentioned, we possess a sure and certain hope that for many of the acute infections antitoxins will be found.

A third noteworthy feature in modern treatment has been a return to psychical methods of cure, in which *faith in something is suggested* to the patient. After all, faith is the great lever of life. Without it, man can do nothing; with it, even with a fragment, as a grain of mustard-seed, all things are possible to him. Faith in us, faith in our drugs and methods, is the great stock in trade of the profession. In one pan of the balance, put the pharmacopœias of the world, all the editions from Dioscorides to the last issue of the United States Dispensatory; heap them on the scales as did Euripides his books in the celebrated contest in the "Frogs"; in the other put the simple faith with which from the days of the Pharaohs until now the children of men have swallowed the mixtures these works describe, and the bulky tomes will kick the beam. It is the *aurum potabile*, the touchstone of success in medicine. As Galen says, confidence and hope do more good than physic—"he cures most in whom most are confident." That strange compound of charlatan and philosopher, Paracelsus, encouraged his patients "to have a good faith, a strong imagination, and they shall find the effects" (Burton). While we often overlook or are ignorant of our own faith-cures, doctors are just a wee bit too sensitive about those performed outside 212
our ranks. They have never had, and cannot expect to have, a monopoly in this panacea, which is open to all, free as the sun, and which may make of every one in certain cases, as was the Lacedemon of Homer's day, "a good physician out of Nature's grace." Faith in the gods or in the saints cures one, faith in little pills another, hypnotic suggestion a third, faith in a plain, common doctor a fourth. In all ages the prayer of faith has healed the sick, and the mental attitude of the suppliant seems to be of more consequence than the powers to which the prayer is addressed. The cures in the temples of Æsculapius, the miracles of the saints, the remarkable cures of those noble men, the Jesuit missionaries, in this country, the modern miracles at Lourdes and at St. Anne de Beaupré in Quebec, and the wonder-workings of the so-called Christian Scientists, are often genuine, and must be considered in discussing the foundations of therapeutics. We physicians use the same power every day. If a poor lass, paralyzed, apparently, helpless, bed-ridden for years, comes to me, having worn out in mind, body, and estate a devoted family; if she in a few weeks or less by faith in me, and faith alone,

takes up her bed and walks, the saints of old could not have done more. St. Anne and many others can scarcely to-day do less. We enjoy, I say, no monopoly in the faith business. The faith with which we work, the faith, indeed, which is available to-day in every-day life, has its limitations. It will not raise the dead; it will not put in a new eye in place of a bad one (as it did to an Iroquois Indian boy for one of the Jesuit fathers), nor will it cure cancer or pneumonia, or knit a bone; but, in spite of these nineteenth-century restrictions, such as we find it, faith is a most precious commodity, without which we should be very badly off.

Hypnotism, introduced by Mesmer in the eighteenth century, has had several revivals as a method of treatment during the nineteenth century. The first careful study of it was made by Braid, a Manchester surgeon, who introduced the terms hypnotism, hypnotic, and nervous sleep; but at this time no very great measure of success followed its use in practice, except perhaps in the case of an Anglo-Indian surgeon, James Esdaile, who, prior to the introduction of anæsthesia, had performed two hundred and sixty-one surgical operations upon patients in a state of hypnotic unconsciousness. About 1880 the French physicians, particularly Charcot and Bernheim, took up the study, and since that time hypnotism has been extensively practised. It may be defined as a subjective psychical condition, what Braid called nervous sleep, resembling somnambulism, in which, as Shakespeare says, in the description of Lady Macbeth, the person receives at once the benefit of sleep and does the effects or acts of watching or waking. Therapeutically, the important fact is that the individual's natural susceptibility to suggestion is increased, and this may hold after the condition of hypnosis has passed away. The condition of hypnosis is usually itself induced by suggestion, requesting the subject to close the eyes, to think of sleep, and the operator then repeats two or three times sentences suggesting sleep, and suggesting that the limbs are getting heavy and that he is feeling drowsy. During this state it has been found that the subjects are very susceptible to suggestion. Too much must not be expected of hypnotism, and the claims which have been made for it have been too often grossly exaggerated. It seems, as it has been recently well put, that hypnotism "at best permits of making suggestions more effective for good or bad than can be done upon one in his waking state." It is found to be of very little use in organic disease. It has been helpful in some cases of hysteria, in certain functional spasmodic affections of the nervous system, in the vicious habits of childhood, and in suggesting to the victims of alcohol and drugs that they should get rid of their inordinate desires. It has been used successfully in certain cases for the relief of labor pains, and in surgical operations; but on the whole, while a valuable agent in a few cases, it has scarcely fulfilled the expectations of its advocates. It is a practice not without serious dangers, and should never be performed except in the presence of a third person, and its indiscriminate practice by ignorant persons should be prevented by law.

One mode of faith-healing in modern days, which passes under the remarkable name of Christian Science, is probably nothing more than mental suggestion under another name. "The patient is told to be calm, and is assured that all will go well; that he must try to aid the healer by believing that what is told him is true. The healer then, quietly but firmly, asserts and reiterates that there is no pain, no suffering, that it is disappearing, that relief will come, that the patient is getting well." This is precisely the method which Bernheim used to use with such success in his hypnotic patients at Nancy, iterating and reiterating, in a most wearisome way, that the disease would disappear and the patient would feel better. As has been pointed out by a recent writer (Dr. Harry Marshall), the chief basis for the growth of Christian Science is that which underlies every popular fallacy: "Oliver Wendell Holmes outlined very clearly the factors concerned, showing (a) how easily abundant facts can be collected to prove anything whatsoever; (b) how insufficient 'exalted wisdom, immaculate honesty, and vast general acquirements' are to prevent an individual from having the most primitive ideas upon subjects out of his line of thought; and, finally, demonstrating 'the boundless credulity and excitability of mankind upon subjects connected with medicine.'"

WILLIAM OSLER.

217

SURGERY

The end of the eighteenth century was made notable by one of the most remarkable and beneficent discoveries which has ever blessed the human race, the discovery of the means of preventing small-pox. On May 14, 1796, Dr. Edward Jenner inoculated James Phipps. When we remember that two million persons died in a single year in the Russian Empire from small-pox; that in 1707 in Iceland, out of a population of thirty thousand, sixty per cent., or eighteen thousand, died; that in Jenner's time "an adult person who had not had small-pox was scarcely met with or heard of in the United Kingdom, and that owing to his discovery small-pox is now one of the rarest diseases," the strong words I have used seem fully justified. But the eighteenth century was not to witness the end of progress in medicine. The advances in the nineteenth century have been even more startling and more beneficent. What these advances have been in the department of medicine has been related by Professor Osler. It is my province to speak only of surgery.

METHOD OF TEACHING

The first advance which should be mentioned is a fundamental one—namely, methods of medical teaching. At the beginning of the nineteenth century there were only three medical schools in the United States: the Medical Department of the University of Pennsylvania, established in 1765; the 218 Medical Department of Harvard, established in 1783; and the Medical Department of Dartmouth, established in 1797. The last report of the Commissioner of Education gives a list of one hundred and fifty-five medical schools now in existence in this country, many of them still poorly equipped and struggling for existence, but a large number of them standing in the first rank, with excellent modern equipment, both in teachers, laboratories, hospitals, and other facilities. The medical curriculum then extended over only two years or less, and consisted of courses of lectures at the most by seven professors who, year after year, read the same course of lectures, without illustrations and with no practical teaching. The medical schools, even when connected with universities, were practically private corporations, the members of which took all the fees, spent what money they were compelled to spend in the maintenance of what we now should call the semblance of an education, and divided the profits. Until within about twenty years this method prevailed in all our medical schools. But the last two decades of the century have seen a remarkable awakening of the medical profession to the need of a broader and more liberal education, and that, as a prerequisite, the medical schools should be on the same basis as the department of arts in every well-regulated college. To accomplish this the boards of trustees have taken possession of the fees of students, have placed the faculties upon salaries, and have used such portion of the incomes of the institutions as was needed for a constant and yet rapid development along the most liberal lines.

COLLEGE HOSPITALS

The first step has been the establishment in connection with most schools of general hospitals in which the various teachers in the college should be the clinical instructors, and where the students 219 would have the means not only of hearing theoretically what should be done to the sick, but of actually examining the patients under the supervision of their instructors, studying the cases so as to become skilled in reaching a diagnosis and indicating what in their opinion was necessary in the way either of hygiene, medicine, or surgical operation. More than that, in most of the advanced schools to-day the students assist the clinical faculties of the hospitals in the actual performance of operations, so that when they graduate they are skilled to a degree utterly unknown twenty years ago.

ESTABLISHMENT OF LABORATORIES

Another step which was equally important, and in some respects even more so, has been the establishment of laboratories connected with each branch of instruction. A laboratory of anatomy (the dissecting room) every medical school has always had, but all the other laboratories are recent additions. Among these may be named a laboratory of clinical medicine, a laboratory of therapeutics, in which the action of drugs is studied; a laboratory of chemistry, a laboratory of microscopy, a laboratory of pathology for the study of diseased tissues, a laboratory of embryology for the study of the development of the human body and of the embryos of animals, a laboratory of hygiene, a laboratory of bacteriology, a laboratory of pharmacy, a surgical laboratory, in which all the operations of surgery are done on the cadaver by each student, a laboratory of physiology, and in many colleges private rooms in which advanced work may be done for the discovery of new truths.

In all these laboratories, instead of simply hearing about the experiments and observations, each student is required to handle the drugs, the chemicals, the apparatus, to do all the operations, to look 220
through the microscope, etc.; in other words, to do all that which is necessary for the proper understanding of the case in hand. In fact, it may be said that in view of the opportunities and the requirements of modern hospitals, it is undoubtedly true that a hospital patient, the poorest of the poor, often has his case more thoroughly studied and more accurately observed than the wealthy patient who is attended at his home. On the other hand, however, so many laboratories with their expensive apparatus and a large staff of assistants mean an enormous increase in the expense of a medical education, for which the student does not pay anything like an equivalent. Hence the need in all of our best modern medical schools for endowments, in order that such work may be carried on properly, and yet the student not be charged such fees as to be practically prohibitory, excepting for the rich, or at the least the well-to-do. I do not hesitate to say that at the end of the second year many a diligent student of to-day is better fitted to practise medicine than was the graduate of half a century ago.

ANATOMICAL MATERIAL

One of the most important means of the study of medicine, and especially of surgery, is a thorough acquaintance with the anatomy of the human body. No one would think of placing an engineer in charge of a complicated piece of machinery, who had never become intimately acquainted with all the parts of such a machine, so that he could take it to pieces and put it together again with ease and intelligence. Yet, until comparatively recently, this knowledge of anatomy was both required of, and yet at the same time the means of obtaining it was forbidden to, the medical student. If he performed 221
an operation and was guilty of negligence or error, due to his want of anatomical knowledge, he was liable to a suit for malpractice. Yet his only means of becoming acquainted with the anatomy of the human body was by stealing the bodies of the dead. In England, up to 1832, this was equally true. A regular traffic in human bodies existed there as well as here, and, by reason of its perils, the cost of bodies for dissection was very great; but it was only a question of money. In his testimony before the Parliamentary Committee, Sir Astley Cooper made a shiver run down the backs of the noble lords who listened to him when he said that in order to dissect the body of any of them it was only necessary for him to pay enough. The large pecuniary profits of such business, when the supply was very small, led to the horrible atrocities of Burke and Hare in Edinburgh in 1832. They deliberately murdered a considerable number of persons, and sold the bodies to the dissecting rooms in that city. The discovery of their crimes finally led to the passage of the Anatomy Act, which has been in force in Great Britain ever since. Similar violations of graveyards in this country have led to the passage in various States of somewhat similar laws, usually giving for dissection the bodies of those who were so poor in

friendship that no one would spend the money necessary for their burial. Even to-day, in a large number of our States, the former anomalous condition of affairs exists. The increase of anatomical material which has resulted from the enactment of wise and salutary laws for this purpose has given a great impetus to the study of anatomy, and has produced a far better educated class of physicians in most parts of the United States within the last few years. The enlightened sense of the community has perceived that to deny the medical schools the means of properly teaching anatomy was a fatal mistake, and resulted in an ignorance of which the community were the victims. As a result, it is 222
possible now, by law, in most States to obtain a reasonable number of cadavers, not only for the study of anatomy, but for the performance of all the usual operations.

MEDICAL LIBRARIES

Along with this there has been throughout this country a marked movement in favor of medical libraries. It is to the credit of the government of the United States that the whole world is debtor to us, not only for the foremost medical library in the world, that of the surgeon-general of the army in Washington, but also for the magnificent index-catalogue, not only of the books, but all the journal articles in every language in the world. No better investment of money was ever made than the establishment of this library, and its allied museum, and the publication of the index-catalogue.

EMBRYOLOGY

As a result of all these means and methods of study, and as a part of the great educational and scientific movement of the century, medical men now take a wholly different view of the normal and abnormal structures of the human body. The study of embryology has shown us that many of the deviations from the normal development of the human body are easily explained by embryology. One of the most important changes in our idea, for example, of tumors is due to the fact that the study of embryology and of the tissues of the embryo have shown us that diseased structures, which lack explanation entirely, when compared with the adult human tissues, readily find their explanation and fall into an unexpected order when compared with the tissues of the embryo. Not only, however, has the study of embryological tissues thrown a flood of light on diseased structures, but we have obtained 223
new views of the relation of man to all creatures, lower in the scale of life. Largely owing to the doctrine of evolution, we now recognize the fact that, so far as his body is concerned, man is kindred to the brutes; that his diseases, within certain limitations, are identical with similar diseases of the lower animals; that his anatomy and physiology are, in essence, the same as the anatomy and physiology of the lower animals, even the very lowest, and that many of his diseases can be best studied in the lower animals, because upon them we can make exact experiments which would be impossible in man. While it is true that each animal has disorders which are peculiar to itself, and that it is not subject to some of the disorders to which man is a victim, and, *per contra*, that man is a victim to some disorders from which animals do not suffer, yet, taking them as a whole, the diseases of man and of animals, and the action of remedies on both, are practically identical. To this I shall have occasion to refer again.

PATHOLOGY

Among the laboratories which I mentioned, one of the most important is that of pathology and morbid anatomy, or the study of diseased tissues and organs. The first work on pathology written in this country was by one of our best-known surgeons, the late Samuel D. Gross, and one of his most important contributions to surgical progress consisted in his persistent advocacy of the need for the study of pathology as a basis for all our means of cure. This is evident, if we consider the illustration I used a moment ago of a steam-engine. Unless he knows precisely the defects of such a machine, the influence of fresh or salt water on a boiler, the influence of rust, the effect of oils, entirely apart from the mere mechanism of the engine, an engineer might make the most serious mistake, resulting in fatal 224 damage, both to the machine and probably to life. So, surgical pathology is the study of the processes of disease, the alterations in the minute structure of tissues and organs, without which no surgeon can be fitted for his task, much less can he be called an accomplished surgeon. All of these laboratories mark the difference between the scientific and the empirical method. The old student of medicine went from case to case, heard many a good maxim, and learned many a useful trick; but, after all, it was only an empirical knowledge which he obtained. It did not go to the foundation of things, it was not scientific, as is the collegiate instruction of to-day.

Having now glanced rapidly at the improvement in medical instruction, let me turn next to a few of the principal discoveries which have made the surgery of to-day so much superior to the surgery of a hundred years ago.

ANÆSTHESIA

After vaccination, the most important medical event of the century is the discovery of anæsthesia. While there were some prior attempts at anæsthesia, practically it dates from October 16, 1846, when Dr. John C. Warren, in the Massachusetts General Hospital, first performed a major surgical operation, without inflicting the slightest pain. I cannot enter into the merits of the various claimants for the credit of first using an anæsthetic, but ether was then for the first time publicly administered by Morton, and the very sponge which was then used is now a precious trophy of the Massachusetts General Hospital. I may, perhaps, quote from an address which I delivered before the Medical and Chirurgical Faculty of the State of Maryland, at their centennial anniversary, in April, 1899, the 225 following in relation to anæsthesia:

> “The news went like wildfire, and anæsthesia was soon introduced into every clinic and at almost every operation throughout the civilized world. Prior to that time a surgical operation was attended with horrors which those who live in these days cannot appreciate. He was the best surgeon who could perform any operation in the least possible time. The whole object of new methods of operating was to shorten the period of frightful agony which every patient had to endure. Every second of suffering saved was an incalculable boon. To submit to any operation required then a heroism and an endurance which is almost incomprehensible to us now. All of the more modern, deliberate, careful, painstaking operations, involving minute dissection, amid nerves and blood-vessels, when life or death depends on the accuracy of almost every touch of the knife, were absolutely impossible. It was beyond human endurance quietly to submit one’s self for an hour, for an hour and a half, for two hours, or even longer, to such physical agony.
>
> “It is a striking commentary on the immediate results of anæsthesia to learn that, in five years before the introduction of ether, only one hundred and eighty-four persons were willing to submit themselves to such a dreadful ordeal in the Massachusetts General Hospital—an average of thirty-seven operations per annum, or three per month.... During the last year, in the same hospital—a Mecca for every surgeon the world over—over thirty-seven hundred operations were performed. It is not an uncommon thing at the present day for any one of the more active surgeons of this country to do as many as four or five hundred operations in a year. I have known as many as nineteen operations to be done in the Jefferson Medical College Hospital in a single 226 day—equalling six months’ work in Boston before the introduction of ether.”

The next year, 1847, witnessed the introduction of chloroform by Sir James Y. Simpson, of Edinburgh. Until I became acquainted with the striking figures just quoted, I had often wondered at the hospital scene in that most touching story, *Rab and His Friends*, by the late gifted and well-beloved physician, Dr. John Brown, of Edinburgh. Nowadays students do not rush into the surgical amphitheatre when they learn that an operation is to be done, but it is taken as a matter of course, for practically every day many operations are done in most of our large hospitals. But, at the time when Rab's mistress was operated upon, an operation, as has been stated, was a very rare event. Few had the fortitude to endure its dreadful pangs. Now, thanks to the blessed sleep of anæsthesia, sufferers from even the most dreadful disorders can have long and difficult operations done, accurate and tedious dissections made, and yet feel not a twinge of pain.

Besides general anæsthesia by ether, chloroform, and a few other agents, there have been introduced several means for producing "local anæsthesia," *i.e.*, agents which destroy the sensibility of the part of the body to be operated upon while not producing unconsciousness. Freezing the part by ice and salt, or by a quickly evaporating spray of rhigolene or chloride of ethyl, are sometimes used. But cocaine and a somewhat similar substance, eucaine, have of late been more extensively used on man, after their harmlessness had been first shown by experiments on animals. In 1885 Corning, of New York, injected a solution of cocaine as near to the spinal cord as was possible, and produced insensibility of all the body below the point of injection by the effect of the cocaine upon the spinal 227 cord. A few years ago Quincke, of Kiel, in Germany, devised a means of puncturing the spinal canal itself in the lumbar region (the lowest part of the small of the back) for the purpose of drawing off some of the fluid for examination. This suggested to Bier, then of Kiel, who was apparently ignorant of Corning's work, that cocaine could be injected through a hollow needle inserted into the spinal canal by "lumbar puncture" and so produce anæsthesia of all the body below this point. This method was published by him in 1899, and was soon repeated in America. In France, however, it has been practised more than elsewhere, Tupper, of Paris, having successfully done over two hundred operations by "spinal anæsthesia." All of the body below the diaphragm can thus be deprived of sensibility. The method will probably never replace ether and chloroform, but in many cases is a valuable aid to the surgeon. But it has its dangers and its inconveniences. The ideal anæsthetic is not that which destroys sensibility and yet leaves the patient perfectly conscious, as spinal anæsthesia does. A patient to whom I recently proposed it for certain special reasons rejected it, saying, with probable truth, that she could never bear the strain of lying on the table perfectly conscious of all that was being done and frightened by any surgical emergency which might easily arise in such a long, difficult, and dangerous operation. The ideal anæsthetic is that which will abolish pain and consciousness without danger to life. The twentieth century will undoubtedly see the discovery of this safe and efficient anæsthetic.

ANTISEPSIS

But the limits of surgical progress were not yet reached. Let me quote again from the address before alluded to:

228

> "Even the introduction of anæsthesia, however, did not rid surgery of all its terrors. The acute pain of the operation was abolished, but the after-suffering, as I know only too well, in my early surgical days, was something dreadful to see. The parched lips of the poor sufferer, tossing uneasily during sleepless nights; wounds reeking with pus, and patients dying by scores from blood-poisoning, from erysipelas, from tetanus, from gangrene, were only too familiar sights in the pre-antiseptic days. Then, again, there arose one of these deliverers of the human race whose name can never be forgotten and whose fame will last so long as time shall endure. Jenner, Warren, and Lister are a triumvirate of names of which any profession may well be proud. Thank God, they all sprang from virile Anglo-Saxon loins! No praise, no reward, no fame is too great for them. That Lord Lister still lives to see the triumph of his marvellous services to humanity is a joy to all of us. And when the profession arose *en masse*, within the last few years, at the International Congress of Berlin, and at the meeting of the British Medical Association in Montreal, and welcomed him with cheer after cheer, it was but a feeble expression of gratitude for benefits which no words can express.

"Before Lister's day erysipelas, tetanus, gangrene, and blood-poisoning in its various phases were the constant attendant of every surgeon. They were dreaded guests at almost any operation; and when in rare cases we obtained primary union without a drop of pus, without fever, and with but little suffering, it was a marvellous achievement. Now it is precisely reversed. The surgeon who does not get primary union without a drop of pus, with no fever, and with little suffering, asks himself—what was the fault in my technic? To open the head, the abdomen, or the chest thirty years ago was almost equivalent to signing the death-warrant of a patient. The early 229 mortality of ovariotomy was about sixty per cent.; two out of three died. Now many a surgeon can point to a series of one hundred abdominal operations with a fatality of only two or three per cent. When Sir Spencer Wells recorded his first one thousand cases of ovariotomy it was calculated that after deducting the years which the patients who died from the operation would have lived had no operation been done the net result of the thousand cases was an addition of twenty thousand years to human life. One thousand ovariotomies under antiseptic precautions at the present would certainly add at least thirty thousand years to human life. Would not such a guerdon be enough for any man?

"This, too, is a direct result of laborious laboratory researches, beginning with the investigations of Liebig and Pasteur on fermentation. Lister went still further. Even before the discovery of the bacteria of suppuration, of tetanus, and of erysipelas he showed us experimentally how, by surgical cleanliness, we could avoid all infection and so banish these pests from our hospitals and bring life and health to many who otherwise would have perished from operations which are now perfectly safe.

"The mortality of compound fractures in the pre-antiseptic days was about sixty per cent. It was one of the most dreaded of all accidents. Its mortality now is perhaps not over three per cent., and the mortality from sepsis after such a fracture, in the hands of well-instructed surgeons, is almost nil. Prior to Lister's day the mortality of major amputations varied from fifty to sixty-three per cent. Now it is from ten to twenty per cent. And so I might go on with operation after operation and show how they have become so safe that one need not dread any, saving exceptional cases.

"These two modern discoveries, anæsthesia and antisepsis, have utterly revolutionized 230 modern surgery. They have made possible operations which, by reason of their length and pain and danger, were utterly unjustifiable in former days, but are now the daily occupation of a busy surgeon. And, far better than this, they have enabled us to bring to homes and hearts, which otherwise would have been broken up and wrung with sorrow, the comfort of life restored to dear ones upon whom depended the happiness and support of the families. Translate figures into happy hearts and prosperous homes if you can, and then you can tell me what Warren and Lister have done for humanity!"

The result of these two wonderful discoveries has been to separate us from the surgical past, as by a great gulf.

"Great theologians, such as a Calvin or a Jonathan Edwards, were they recalled to life, could discourse as learnedly as ever of predestination and free will; great preachers, as a Beecher or a Spurgeon, could stir our souls and warm our hearts as of old; great jurists, as a Justinian or a Marshall, could expound the same principles of law which hold good for all time; great forensic orators, as a Burke or a Webster, could convince us by the same arguments and arouse us by the same invectives or the same eloquence that made our fathers willing captives to their silver tongues. But to-day, so rapid has been our surgical progress, a Velpeau, a Sir William Ferguson, or a Pancoast, all of whom have died within the last thirty years, could not teach modern surgical principles nor perform a modern surgical operation. Even our every-day surgical vocabulary—staphylococcus, streptococcus, infection, immunity, antisepsis and asepsis, toxin and antitoxin—would be unintelligible jargon to him; and our modern operations on the brain, the chest, the 231 abdomen, and the pelvis would make him wonder whether we had not lost our senses, until, seeing the almost uniform and almost painless recoveries, he would thank God for the magnificent progress of the last half-century, which had vouchsafed such magical, nay, such almost divine, power to the modern surgeon."

THE SURGERY OF WAR

One of the immediate consequences of the introduction of the antiseptic method has been a remarkable mitigation of the horrors of war. Our recent war with Spain has proved, and the present military operations in the Philippines and of the British in South Africa will still further prove, its advantages. Witness a little book written by Professor von Esmarch, of Kiel, Germany, with the apt title, *The Fight of Humanity Against the Horrors of War*; with an appendix, entitled, "The Samaritan on the Battle-field." One of the most valuable means for the preservation of human life is carried by every soldier in a modern civilized army as a part of his regulation outfit, a "First Aid Package" for the treatment of any wound or injury; and one of the most valuable and interesting papers read before the American Surgical Association, at its meeting in Chicago in 1899, was by Professor Senn on the "First Aid Package." This first aid package contains an antiseptic dressing, which can be applied to all but the gravest wounds for the purpose of preventing infection, which is the principal danger to life after accident or injury. The universal testimony of our surgeons in Cuba was that by its use most wounds were prevented from becoming infected, and, therefore, inflamed, and that the number of operations was greatly diminished by reason of its use.

232

BACTERIOLOGY

In experimental science, two methods of progress are observed; first, in actual practice certain methods are adopted because they are found to be the most advantageous and useful, though we cannot explain why it is so—*i.e.*, practice outstrips theory. Again, as a result of experimental investigation, certain facts are discovered which explain why the practical methods just alluded to are the best, and this in turn suggests further improvements in our practice—*i.e.*, theory outstrips practice and enlarges its domain. Thus outstripping theory, the practical advance made by Lister was an example of the first. His striking results in turn stimulated scientific observers to make new discoveries of the greatest importance, and thus science immensely improved and widened our practical methods.

No definite year or day can be assigned as the birth-date of Lord Lister's antiseptic methods, as we can, for instance, for vaccination or for anæsthesia. We may assume, at least for this counrty, the summer of 1876 as the starting-point. During that year Lord Lister attended the International Medical Congress held in Philadelphia, and demonstrated his then methods and convinced a few surgeons of their immense advantages. Even before that date there had been very many experiments and observations, especially on the blood. In 1863 Davaine, in France, had discovered little rod-like bodies in the blood in wool-sorters' disease, or anthrax, which he named from their shape "bacteria," or "little rods." This name has been adopted for all forms of germs, though many of them are not rod-like in their shape. Not until 1881 was the cause of inflammation and suppuration (the formation of pus or "matter") discovered. In that year Ogston, of Aberdeen, published experiments which he believed demonstrated the fact that certain bacteria were the cause of suppuration. Since then this has been 233
amply confirmed not only by experiments upon animals, but by observation in man. In 1882 Robert Koch, of Berlin, discovered the cause of tuberculosis, a little rod-like body, which is named the "bacillus" of tuberculosis. In 1883 Fehleisen discovered the germ of erysipelas, and in 1887 Nicolaier and Rosenbaum discovered the bacillus of tetanus or lockjaw. So recent have been the discoveries in bacteriology which have led to vast improvements in our methods of treatment of wounds and the performance of operations.

While the principles established by Lord Lister have remained unchanged, the details in the treatment have been greatly simplified and made more efficient. For the information of the general reader, let me state a few facts. Bacteria are divided into two principal classes, in accordance with their form. One, known as "cocci," from the Greek word coccus—"berry"—may be likened to billiard-balls. Some of these occur in bunches, which have been likened to bunches of grapes, and hence are called, again from a Greek term, "staphylococci." Others are arranged in chains, like beads, and are called "streptococci." These last are very much more virulent and dangerous than the staphylococci. Both of these produce pus or matter, and they are the most widely diffused and most common forms found in infected or suppurating wounds. One form is the cause of erysipelas. A second form, known as "bacilli," may be likened to a lead-pencil. Among the various bacilli that have been discovered are those of tuberculosis, glanders, tetanus or lockjaw, etc. I omit many others found in medical disorders, as they do not concern this paper. How important these discoveries are may be seen by the following facts: Tuberculosis, next to that of suppuration, is, perhaps, the most widely extended infection to 234
which man, as well as animals, is liable. We are all familiar with it in the form of "consumption," but the non-medical reader is, perhaps, not aware of the fact that it affects not only the lungs, but also the bowels in consumption of the bowels; the bones, as is seen by every surgeon almost daily, and especially as the cause of the crooked backs seen in spine diseases; in the joints, as is seen in hip-joint disease, white swelling of the knee, ankle-joint disease, and similar disease of all the other large joints of the body; in the brain, in tubercular meningitis; in the abdominal cavity, in tubercular peritonitis; in the skin, in certain forms of ulceration, commonly called lupus; in the glands, as in the swollen glands, or "bunches," in the neck, and endless other varieties which I need not name.

The bacillus of lockjaw is found in great abundance around stables, and this explains the fact that hostlers, drivers, cavalrymen, all of whom had to do with horses, are especially liable to attacks of lockjaw. Moreover, certain bacteria thrive best when exposed to the open air. Other bacteria, and among them the bacilli of lockjaw, thrive best when the air is excluded, and this explains the danger of treading on a rusty nail, which is popularly and rightly known as peculiarly liable to produce lockjaw. The reason is not because it is a nail, nor because it is old, nor because it is rusty, but because from the earth in which it lies it is most apt to be the means of introducing into a punctured wound the bacilli of lockjaw. Such a wound bleeds but very little, the blood soon crusts and excludes the air, and if any of the bacilli of lockjaw have been carried into the body, they find in such a closed wound, from which the air is excluded, the most favorable conditions for growth and infection of the whole body. Knowing these facts from experiment, the treatment is clear. Lay open such a wound and disinfect it.

These two forms, the "cocci," or berry-like bacteria, and the "bacilli," or rod-like bacteria, 235
comprise the great majority of dangerous bacteria.

It must be remembered that there is an enormous number of bacteria which are not dangerous; some of them are entirely harmless even if introduced into the human body. Others are the bacteria of decomposition, or putrefaction, which are known as "saprophytic" bacteria. All of the harmless ones are known as "non-pathogenic," that is, non-producers of disease. Those which produce disease are known as "pathogenic," and those which produce suppuration as "pyogenic" or pus-producing bacteria.

All of these bacteria are plants, and not, as is very frequently supposed, animals of a low form. The danger from their introduction into the body can be best appreciated, perhaps, by the statement of Belfield, who estimated that a single bacterium which weighs, approximately, only the 1-40,000,000 part of a grain, if given plenty of food and plenty of "elbow room," would so rapidly develop that in three days it would form a mass weighing 800 tons! It is the old story of the blacksmith who was to get a penny for the first nail, two for the second, four for the third, and so on till a set of shoes would cost more than Crœsus could pay for.

The effect of the bacteria has been determined by experiment to be proportionate to the dose. A cubic centimetre is a cube two-fifths of an inch on each side. One-tenth of such a cube of pure culture of one bacterium (*Proteus vulgaris*) contains 225,000,000 bacteria, and if injected under the skin of a rabbit will produce death. Less than 18,000,000 will produce no effect whatever. Of one kind of staphylococcus, if 250,000,000 are introduced under the skin of a rabbit there will be produced a small abscess, but it requires 1,000,000,000 to produce speedy death. On the other hand, of the bacillus of lockjaw it requires only 1000 to produce death, so virulent is this germ. 236

Moreover, their effect on tissues and persons in different states varies very much. Thus, it is found that when a certain number of bacteria are injected into the cavity of the abdomen of an animal, if the animal is healthy and the peritoneum (the thin lining membrane of the abdomen) is healthy, the animal will recover perfectly well; but if the peritoneum be scraped and torn (and it must be remembered that the healthy peritoneum is devoid of sensation), that the same dose which before was harmless will now produce a violent peritonitis and very likely death. The practical lesson from this experiment upon animals is very evident. Every surgeon who opens the abdomen is most careful, if possible, not to injure the peritoneum, but manipulates with the greatest care lest fatal results follow any serious injury to that membrane. So, too, if the general health be impaired, it is found that an injection from which a healthy animal would recover will be followed by fatal consequences if the general health is below par. Again, if an animal has a simple fracture of his thigh-bone, and that is the only injury that he receives, no infection from the exterior having occurred, he will make a good recovery; but if at the same time he receives a lacerated wound, it may be even in another part of the body, and this wound, not being cared for most scrupulously, becomes infected, the infection will fasten on the distant spot of least resistance, the broken thigh-bone, and will produce a most dangerous and very frequently fatal form of inflammation.

I need scarcely point out in this connection, as in fact throughout this entire consideration of bacteriology, how important a part in its development has been played by experiment upon animals. The experimental facts just stated are of vital importance in the treatment of surgical diseases, and 237
evidently could not have been determined upon mankind. It is not too much to say that had vivisection been restricted or prohibited the surgery of to-day would be the barbarous surgery of thirty years ago.

Even granting that an enormous number of the bacteria are harmless, the wonder is that with so many foes on every hand we live an ordinary lifetime. Fortunately, however, in the human body there is not only a lack of food sufficient and “elbow room” enough for them to work their dire effects, but there is that which “makes for righteousness” in our physical organization as well as in our souls.

The moment that bacteria are introduced into the human body a certain number of cells hasten to destroy them. These are called “phagocytes” or devouring cells, because they eat up the bacteria. Whether the patient survives or dies depends on whether the bacteria get the upper hand of the phagocytes or the phagocytes the upper hand of the bacteria.

These statements are very easy to make, but the results have only been obtained by prolonged and laborious investigations in the laboratory and by experiments upon animals which have demonstrated these facts.

The bacteria are recognized by various methods: First, by form. Many which are identical in appearance, however, differ greatly in effects. A handful of turnip-seed and a handful of rape-seed look very much alike, but if they are planted the plants differ so greatly that we can recognize the difference in the seed by the difference in the crop; hence the second method of recognizing differences in bacteria is by planting them. Different methods have been practised. Some are sown on the raw surface of a potato; others on bread paste; others in certain jelly-like materials, such as gelatine or agar-agar. It was soon found as a result of these experiments that the bacteria flourished best, some 238
in one soil, some in another. Again, the crops of mould which come from them differ greatly in color, some being black, some red, some white, some yellow, etc. A third method also is by staining them with various dyes, when it is found that some bacteria will take one stain best, others will take another, and so on through the whole list.

At first it was thought that these bacteria existed chiefly in the air, and hence in Lister’s early methods powerful spray-producing apparatus were used; but while it is true that they do exist in the air, it is found that this is not the principal source of infection. There is no substance (which has not been disinfected) that is not covered with the germs of these little plants. They exist in our food and drink; but the intestine is, one may say, a natural home in which many exist without harm to the body. For surgical purposes their existence is most important, first, in the earth, where, as I have already shown, the bacillus of lockjaw is most frequently found. So, too, the bacillus of wool-sorters' disease (*Anthrax*) exists in the earth. If an animal dying of anthrax is buried, worms coming from the carcass up through the ground carry the infection, so that other animals grazing over this surface will become readily infected. The means by which we can avoid infection from the earth is very evident, viz., every person who has been run over by the cars or who has fallen on the ground and broken his leg, etc., must have the wound most carefully cleansed from all dirt. If this is scrupulously done the danger of tetanus or other similar earth-born bacterial disease is almost nothing.

A still greater danger to every patient, however, is found in the clothing, in the skin, and all dressings which are applied to wounds. The skin is full of bacteria of the most dangerous kind; even the spotless hands of the bride, in the eyes of the surgeon, are dirty. No one can touch a wound with 239 ordinarily clean hands without infecting it. All clothing, dressings—*e.g.*, lint and soft linen rags, and such like—are full of bacteria of the most dangerous kind. Perhaps the most dangerous place is the space under the nails of the surgeon's hand, for the mere mechanical removal of any dirt under the nails by cleansing them does not make them clean surgically. The nails must be cut short and prepared in a way I shall mention directly, or they are full of peril to any patient into whose wound a non-disinfected finger is introduced. Again, another source of infection which thirty years ago we never thought of is our instruments. Then instruments were washed with soap and water and were made clean to the eye, but they were still covered with invisible death-dealing bacteria which hid especially in the joints and irregularities of the surface of all instruments.

All of these somewhat detailed statements lead up to a consideration of the difference between the old surgery and the new. Thirty years ago when an operation was to be performed or an accident cared for we laid out our instruments which were visibly clean, used them with hands which were as clean as those of any gentleman, and applied soft linen rags, lint, and other dressings. To-day we know that these apparently clean instruments, hands, and dressings are covered with bacteria, which produce infection, and, therefore, suppuration, and frequently run riot in blood-poisoning, erysipelas, lockjaw, and death.

How does a modern surgeon perform an operation? All bacteria can be killed by heat. Cold has no effect upon them, but the temperature of boiling water (212° Fahr.) is sufficient to destroy them all usually within fifteen or twenty minutes; hence, first, instruments are all boiled; and, secondly, dressings are either steeped in such solutions as have been found to destroy the bacteria, such as 240 carbolic acid or corrosive sublimate, or other preparations, or, still better, are placed in sterilizers, that is to say, metal cylinders, which are then filled with steam, usually under pressure, so as to obtain a temperature of 240° Fahr., and thus make sure of the death of the bacteria. Unfortunately, our hands cannot be boiled or steamed, but the modern surgeon first uses soap and water most vigorously over his hands and arms up to the elbow. The nails are cut short and the scrubbing-brush is especially applied to the nails so as to clean the fingers at the ends. Then by various means, such as pure alcohol, which is one of our best disinfectants, or solutions of corrosive sublimate, and other means too technical to mention, the hands are sterilized. Rubber gloves are frequently used, so as to preclude infection, as they can be steamed to 240° Fahr. Removing at least his outer clothing, the surgeon puts on a cotton gown which has been steamed and so made free from bacteria. Not a few surgeons also wear sterilized caps, so that any bacteria in the hair will not be sifted into a wound, and some wear respirators of sterile gauze over the mouth and beard for the same reason. All the dressings have been sterilized by superheated steam. All the threads by which blood-vessels are tied have been either boiled or otherwise sterilized. All the material for sewing up the wounds, and the needles with which they are sewn, have been similarly disinfected. The skin of the patient is also sterilized, usually the day beforehand, in the same manner in which the surgeon's hands have been disinfected, and are disinfected a second time just at the moment of the operation. If the case is one of accident, such as a crushed leg from a trolley-car, all of the dirt is most carefully washed away with soap and water, and the parts are disinfected, not only on the exterior, but also by prolonged washing with some cleansing 241 agent in the interior of the wound, the patient being under the influence of ether, of course.

It is easily seen from such a description of a modern operation that no case can receive due care in one of our modern homes, even the best. The facilities do not exist, and hence surgeons are more and more declining to do operations, whether for accident or disease, in private houses, except in a case of absolute necessity, and a happy custom is growing more and more in favor with the community of having all operations and all accidents cared for in a well-equipped hospital.

RESULTS OF MODERN SURGERY

As the result of our ability to perform operations without pain, thanks to anæsthesia, and our ability to perform operations without infection, and, therefore, almost without danger, thanks to antisepsis, the range of modern surgery has been enormously increased. Unless one has lived through the old surgery and into the new he scarcely can appreciate this widening of the field of operative surgery. Thirty years ago, in consequence of the great danger of opening the head, the chest, or the abdomen, or, in fact, of making an incision anywhere about the body, the surgeon never dared to interfere until he was obliged to do so. Hence, not only were many modern operations not even thought of, but in obscure cases we had to wait until time and disease developed symptoms and physical signs such that we were sure of our diagnosis, and then, knowing that death would follow if we did not interfere, we ventured to operate. Now we anticipate such a fatal termination, and in most cases can avert it. In perhaps no class of cases has the benefit of this immunity from infection and danger been shown than in the obscure diseases of the brain and the abdomen. To-day, if we are 242
uncertain as to whether there is serious danger going on which, if unchecked, will result in death, we deliberately open the one cavity or the other, in order to find out the exact state of affairs. Supposing that the mischief is trifling, or even that there is no mischief, we then know how to deal with the symptoms which have been puzzling us. So far as the exploratory operation is concerned, the patient recovers from it in a short time, and, meantime, perhaps has also been cured of the symptoms which were before so ill understood. If any serious disease is found, in the majority of cases we can cope with it successfully. Before the days of antisepsis and anæsthesia the field of operation was greatly restricted, and practically the removal of tumors, amputations, and a few other operations were all that were done. Now all the then inaccessible organs are attacked with an intrepidity born of an assurance of safety. Recovery usually sets the seal of approval on the judgment of the surgeon. Thirty years ago, taking all operations together, fully one-third of our patients died, many of them often from slight operations which were followed by infection. To-day, including even the far more grave operations which are now done, the general mortality will scarcely exceed five per cent., and many surgeons are able, in a series of several hundred operations, to save ninety-seven out of every hundred patients!

SERUM TREATMENT

Another remarkable recent discovery, the result of numerous and careful investigations in the laboratory, is a wholly new means of treatment, viz., that method which is known as orrhotherapy, or serumtherapy, or the treatment by injecting certain antitoxins under the skin by a hypodermatic syringe. It would lead me too far to enter into the theory upon which these were first used. Suffice it to 243
say that in the blood of an animal that has passed through a certain disorder the liquid part of the blood contains an antidote or antitoxin. If a certain amount of this is injected under the skin of an animal or man suffering from the same disorder in its incipient stages, the antitoxin prevents the development of the disease. The use of this method has thus far been much more medical than surgical, and its results in diphtheria and other medical disorders have been perfectly marvellous. In surgery, however, less favorable results have been obtained, but in all probability in the future we shall be able to do for some of our surgical disorders what the physician can do to-day for diphtheria. [For the results in diphtheria, see Professor Osler's paper.]

There has also been discovered another means which in surgery has rendered some valuable service. From certain organs, as, for instance, the thyroid gland (the gland whose enlargement produces goitre), we can obtain a very potent extract of great value. In cases of goitre very noteworthy results have already been obtained by the administration of the thyroid extract. A number of other organs in the body of animals have been used to combat certain disorders in the human body with advantage. The chief development of both of these new forms of medication, however, will take place in the twentieth century.

INSTRUMENTS OF PRECISION

Another direction in which the century has seen enormous progress is in the introduction of instruments of precision. When I was a student in the early 60's, instruction in microscopy was conspicuous only by its absence from our medical curriculum. Now every student who graduates is 244 more or less of an accomplished microscopist, and carries into his practice the methods and observations which the microscope furnishes. At the same period I remember being greatly interested in a discussion which two of my teachers had as to whether it was possible to make an application accurately to the vocal chords in the larynx. Now every tyro in medicine makes such applications to the larynx as a routine procedure in cases requiring it, and similar methods have been applied by the ophthalmoscope to examine the interior of the eye; the rhinoscope, to examine the interior of the nose; the otoscope, for examination of the ear; and other similar instruments for examining all the other hollow organs in the body. If I add to these the hypodermatic syringe; the aspirator, which may be described as a large hypodermatic syringe for suction instead of injection; the clinical thermometer, which was introduced in the late 60's; the hemostatic forceps, for controlling hemorrhage by seizing the blood-vessels and clamping them till we have time to tie them; and other instruments intended to facilitate our operative methods, it will be seen at once that the armamentarium of the modern surgeon is very different from that of his predecessor at the beginning, or even at the middle, of the century.

THE RÖNTGEN RAY

One of those extraordinary discoveries which startle the whole world came nearly at the end of the nineteenth century, in the winter of 1895–96. At that time a modest professor in the University of Würzburg announced that he could readily see the skeleton inside the body through the flesh! Naturally, the first announcement was received with almost absolute incredulity; but very soon his discovery was confirmed from all sides, and it has now taken its place among the recognized 245 phenomena of science. By means of certain rays, which, being of unknown nature, were called "X"-rays, after the well-known mathematical X, or unknown quantity, Professor Röntgen has shown us that not only can the bones be seen, but that almost every substance in the body can be seen and reproduced in pictures. The reason for this is because they are all obstacles to the passage of these X-rays and so produce shadows on a sensitized photographic plate. If the exposure is sufficiently prolonged the rays penetrate even through the bones and act upon the photographic plate, so that no shadow remains. If the rays are allowed to penetrate for a shorter time the bones show dense shadows, and one can get a light shadow of the soft parts. If the exposure is still shorter, then we can recognize the dense shadow of the bone, the much less dense shadows of the muscles, and the still lighter shadows of the layer of fat immediately under the skin. The heart can be seen beating, and its shadow is now a well-recognized feature in skiagraphs of the chest. At first it was thought impossible to discover anything inside the bony skull, but there are now on record nearly a score of instances in which bullets have been detected within the skull, and after trephining have been found and removed exactly at the location indicated. It is a very common thing now to locate a piece of steel or other similar foreign bodies within the eyeball by the method of Dr. Sweet, or some similar method, within one or two millimetres (a millimetre is one-twenty-fifth of an inch). It is now well recognized that even stones in the kidney will throw shadows sufficiently strong for them to be recognized, and by noting their level in relation to the vertebræ we can tell precisely in what part of the kidney to make the incision in order to find and remove them. It has happened to myself and many other surgeons in the past to cut down upon a kidney, believing that there was a stone in the kidney, only to find that we had been misled by the apparently clear symptoms of such a foreign body. In future no such mistake should be made by any surgeon within reach of a skilful skiagrapher. Unfortunately, gall stones and numerous other foreign bodies, vegetable substances such as beans, corn, wood, etc., being as transparent to the X-rays as are the soft parts, are not revealed by means of this new method of investigation; but cavities in the lung, abscesses in bone, and similar diseases which produce thinning of the lung, bone, and other such organs, and so lighten instead of deepen the shadows, can now be recognized by means of light spots in the pictures as well as others by means of a shadow. 246

I spoke a moment ago of the need of a “skilful” skiagrapher, for it must be remembered that there may be the same difference in the personal skill, and, therefore, in the reliability of the results in skiagraphy as there is in photography. A poor photographer will get very different results from a skilful one, even if he uses precisely the same quality of plates and precisely the same camera. Personal skill and experience in the skiagrapher is, therefore, one of the most important elements in success. It must be remembered also that the X-rays in not a few cases may mislead us. I have, personally, fractured a bone on account of deformity, taken an X-ray picture immediately after the operation, the picture showing not the slightest evidence of a fracture, which I absolutely knew existed. Moreover, foreign bodies found on the outside of the person may mislead us, as, for example, the metal part of suspenders, a coin in one’s pocket, and such like. They look in the picture as if they were inside rather than outside the body, and any article the shape or size of which would not reveal its nature might easily be mistaken for a foreign body within the patient. 247 Therefore, in many cases only an expert can determine precisely what the skiagraph means. I especially mention this, because there is a tendency at present to utilize skiagraphs in court in order to convince the jury that such a picture is an evidence of malpractice. Such pictures always need an interpreter in order to judge correctly of their meaning. It is precisely as if the jury were asked to look through a microscope. I have been myself accustomed to use the microscope for thirty years, but there are many instances even yet in which I am obliged to ask a pathologist or bacteriologist what I really am looking at in the microscope. While one may make a mistake of small moment in some cases, yet if a man’s life or liberty or purse is at the mercy of a jury which does not know how to interpret a skiagraph, and, may, therefore, give a verdict which is “precisely wrong,” as Professor Lincoln, my old teacher of Latin, used to call many of our translations, it will be a very serious matter and lead to gross injustice.

CITY AND VILLAGE HOSPITALS

Another great improvement in our means of caring for our surgical patients is the establishment of hospitals all over the land. These, happily, are not limited to our great cities, but in every country town and not a few large villages small but well-equipped and well-managed hospitals have been established which have done incalculable good. It is not too much to say that every city or town establishing such a hospital is repaid a hundredfold.

TRAINED NURSES

The trained nurse has fortunately come to stay. In fact, our antiseptic methods as above described have made the trained nurse indispensable. 248 The old nurse, who, by many clumsy experiments on her patients, had obtained a certain rule-of-thumb knowledge of the care of the sick, can no longer assist in a surgical operation or properly care for any surgical patient. The modern nurse must of necessity be a well-educated, well-trained woman, knowing thoroughly modern antiseptic methods, and on the alert to observe every symptom of improvement and every signal of danger.

Without a well-trained nurse it is impossible at the present day properly to care for any serious surgical case, and I gladly bear witness to the intelligence, fidelity, and skill of scores of nurses who have assisted me, and without whom I should have felt as one blade of a scissors without its fellow.

SPECIAL OPERATIONS

Amputations and Compound Fractures.—Having now traced the different modes of thought which have aided surgical progress in the nineteenth century and the improved means of investigation, let us turn finally to the progress in individual operations. As to amputations and compound fractures, I have already indicated the immense improvements which have followed the introduction of anæsthesia, and especially of antisepsis, which have brought the mortality of amputations down from fifty or sixty per cent. to ten or fifteen per cent., and in compound fractures, once so dreaded, since the mortality was not infrequently as high as two out of three, to a relatively insignificant danger.

Tumors.—In no department, perhaps, has the introduction of antisepsis, and the use of catgut and silk ligatures after the antiseptic method, brought about a greater improvement than in operations for tumors. The startling reluctance of Sir Astley Cooper to operate on King George IV. for so simple and small a tumor as a wen, lest erysipelas might follow and even destroy his life, is in marked contrast 249
with the success and therefore the boldness of modern surgeons. Tumors in all parts of the body, whether they be external or internal, whether they involve the wall of the chest or are inside the abdomen, are now removed with almost perfect safety. Anæsthesia has made it possible to dissect out tumors in so dangerous a region as the neck, where the surgeon is confronted with adhesions to the jugular vein, the carotid artery, and the nerves of the neck and of the arm, with the greatest impunity. Such an operation not uncommonly lasts from three-quarters of an hour to an hour and a half, and involves often the removal of two or three inches of the jugular vein and many of the large nerves, the removal of which a few years ago would have been deemed an impossibility.

Goitre.—One of the most striking instances of progress is operations on goitre. Writing in 1876, the late Professor Samuel D. Gross noted it as something remarkable that Dr. Green, of Portland, Maine, had removed seven goitres with two deaths, and the late Dr. Maury, of Philadelphia, had extirpated two goitres with one death. In marked contrast to this Professor Kocher, of Berne, in 1895, reported one thousand cases, of which eight hundred and seventy were non-cancerous, and he lost of these last but eleven cases, or a little over one per cent. In 1898 he reported six hundred additional cases, with only one death in the five hundred and fifty-six non-cancerous cases, or a mortality of only 0.1 per cent. It will be seen, therefore, that an operation which a few years ago was excessively fatal has become almost, one might say, a perfectly safe operation.

Surgery of the Bones.—Operations on bones, apart from amputations, show also a similar
improvement. In cases of deformity following fracture we now do not hesitate to cut down upon the 250
bone and refracture it or remove the deformed portion, join the ends together, dress the part in plaster of Paris to secure fixation, and have the patient recover with little or no fever and no suppuration. Above the elbow a large nerve runs in a furrow in the arm bone, and in case of fracture this is liable to be torn and a portion of it destroyed. The result of it is paralysis of all the muscles on the back of the forearm from the elbow down and consequent inability to extend either wrist or fingers, making the hand almost useless. In a number of cases the nerve has been sought for and found, but the ends have been too far apart for successful union and sewing them together. In such cases we do not hesitate now, in order to bring the two ends of the nerve together, to remove one or two inches of the arm bone, wire the shortened bone, sew the now approximated ends of the nerve together, put the arm in plaster, and as soon as the wound is healed, with appropriate later treatment to the muscles we can obtain in a reasonable number of cases a perfect, or almost perfect, union of the nerves with a re-establishment of the usefulness of the hand.

In very many cases the bones are deformed as a result of rickets, and in some cases in consequence of hip-joint disease. In such cases the leg is crooked or flexed, and cannot be used for walking. Such cases of stiff joints and crooked legs are now operated on, one might say, wholesale. At the International Medical Congress, held in Copenhagen in 1884, Professor Macewen, of Glasgow,

reported 1800 operations on 1267 limbs in 704 patients, in which he had sawn or chiselled through the bones so as to fracture them, placed them in a straight position, and after a few weeks the bone has become consolidated and the leg or arm made straight. Every one of these operations was successful, excepting five cases, and even these deaths were not due to the operation, but to some other disorder, 251
such as an unexpected attack of pneumonia, diphtheria, or scarlet fever.

Surgery of the Head and Brain.—In the surgery of the head we find one of the most remarkable illustrations of the modern progress of surgery. Fractures of the skull have been the most dangerous and fatal of accidents until within a short time. Of course, many of them must necessarily, even now, be fatal, from the widespread injury to the bones and the brain. But our modern methods, by which we can disinfect the cavities of the ear, the nose, and the mouth, with which these fractures often communicate, and through these avenues become infected, are so successful that such cases, instead of being looked upon as hopeless, are in a majority of instances followed by recovery. Even gun-shot wounds, in which the ball may remain inside the cavity of the head, are successfully dealt with, unless the injury produced by the ball has been necessarily fatal from the start. Fluhrer, of New York, has reported a very remarkable case of gun-shot wound, in which the ball entered at the forehead, traversed the entire brain, was deflected at the back of the skull, and then pursued its course farther downward in the brain. By trephining the skull at the back he found the ball, passed a rubber drainage tube through the entire brain from front to back, and had the satisfaction of seeing the patient recover.

Until 1884 it was excessively difficult to locate with any degree of accuracy a tumor within the brain, but in that year Dr. Bennett, of London, for the first time accurately located a tumor within the skull without there being the slightest evidence on the exterior of its existence, much less of its location. Mr. Godlee (surgeons in England are not called "Dr.," but "Mr.") trephined the skull at the point indicated, found the tumor, and removed it. True, this patient died, but the possibility of 252
accurately locating a tumor of the brain, reaching it and removing it, was now demonstrated, which is far more important to humanity at large than whether this individual patient survived or not. Since then there have been a very large number of tumors successfully removed. The latest statistics are those of Von Bergmann, of Berlin, in 1898. He collected 273 operations for brain tumors, of which 169 (61.9 per cent.) recovered, and 104 (38.1 per cent.) died. This is by far the best percentage of results so far reported, but there is reason to believe that with the constant improvement in our ability to locate such tumors and in our methods of removing them, the mortality rate will be still further lessened.

Even more successful than the surgery of brain tumors has been the surgery of abscess of the brain. I have no available statistics of the exact numbers, but it is certain that several hundred have been operated on, and with even better success than in the case of brain tumors. The most frequent cause for such abscesses is old and neglected disease of the ear. No child suffering from a "running from the ear," which is especially apt to follow scarlet fever and other similar disorders, should be allowed to pass from under the most skilled treatment until a cure is effected. This is the commonest cause of abscess of the brain. The inflammation in the ear, which begins in the soft lining of the cavities of the ear, finally extends to the bone, and after years of intermittent discharge, will suddenly develop an abscess of the brain, which, if not relieved, will certainly be fatal. Prompt surgical interference alone can save life, and, happily, though we cannot promise recovery in all, a very large percentage of success is assured.

In epilepsy, as a result of injuries of the head, in a moderate number of cases, we can obtain a cure
of the disease by operation, but in the great majority of cases, and, one may say, practically in all of 253
the cases in which the epilepsy originates "of itself," that is to say, without any known cause, it is useless to operate, certainly at least after the epileptic habit has been formed. Possibly were operation done at the very beginning we might obtain better results than experience thus far has shown us is possible.

Very many cases of idiocy are constantly brought to surgeons in the hope that something can be done for these lamentable children. Unfortunately, at present surgery holds out but little hope in such cases. In a few exceptional instances it may be best to operate, but a prudent surgeon will decline to do any operation in the vast majority of cases.

Surgery of the Chest and Heart.—The chest is the region of the body which has shown the least progress of all, and yet even here the progress is very marked. When, as a result of pleurisy, fluid accumulates on one side of the chest, even displacing the heart, we now do not hesitate to remove an inch or two of one or more ribs and thoroughly drain the cavity, with not only a reasonable, but in a majority of cases, one may almost say, a certain, prospect of cure. We have also entered upon the road which will lead us in time to a secure surgery of the lung itself. A few cases of abscess, of serious gun-shot wound, attended by otherwise fatal hemorrhage, and even of tubercular cavities in the lungs have been successfully dealt with, but the twentieth century will see, I have no doubt, brilliant results in thoracic surgery.

One of the most striking injuries of the chest has recently assumed a new importance, viz., wounds of the heart itself. In several instances an opening has been made in the bony and muscular walls of the chest, and a wound of the heart itself has been sewed up. The number is as yet small, but there have been several recoveries, which lead us to believe that here, too, the limits of surgery have 254
by no means been reached.

Surgery of the Abdomen.—Of the abdomen and the pelvis a very different story can be told. These cavities might almost be called the playground of the surgeon, and the remarkable results which have been obtained warrant us in believing that even greater results are in store for us in the future.

In the earlier part of this article I spoke of the advantages of the study of the pathological anatomy or the diseased condition of individual organs. Perhaps no better illustration of the value of this can be given than in the studies of appendicitis. This operation has been one of the contributions to the surgery of the world in which America has been foremost. While there were one or two earlier papers, Willard Parker, of New York, in 1867, first made the profession listen to him when he urged that abscesses appearing above the right groin should be operated on and the patient's life saved. But it was not until Fitz, of Boston, in 1888, published his paper, in which he pointed out, as a result of a study of a series of post-mortem examinations of persons dying from such an abscess above the right groin, that the appendix was the seat of the trouble, that this so frequent disease was rightly understood and rightly treated.

As a result of the facts gathered in his paper, the treatment was perfectly clear, not only that we ought to operate in cases of abscess, but that in the case of patients suffering from two or more attacks, and often from even one attack of appendicitis, the appendix should be removed to prevent such abscess.

The mortality in cases in which such an abscess has formed is, perhaps, quite twenty or twenty-five per cent., whereas, if patients are operated on "in the interval," that is to say, between attacks, when the abdominal cavity is free from pus, the mortality is scarcely more than two or three per cent., 255
and may be even less than that.

Surgeons are often asked whether appendicitis is not a fad, and whether our grandfathers ever had appendicitis, etc. As a matter of fact, in my early professional days, appendicitis was well known. It was called "localized peritonitis" or localized "abscess," but while the disease was very frequent, its relation to the appendix was not recognized until from his study of its pathology an American pointed it out. Even now European surgeons, with a few exceptions, are not alive to the need for operation in such cases.

There is little doubt that the great prevalence of grippe during the last few years has increased the number of cases of appendicitis, both of them being catarrhal conditions of the lining membrane of the same continuous tract of the lungs, the mouth, the stomach, and the intestines.

One of the most fatal accidents that can befall a patient is to have an ulcer of the stomach perforate so that the contents of the stomach escape into the general abdominal cavity. Until 1885 no one ventured to operate in such a case. In an inaugural dissertation by Tinker, of Philadelphia, two hundred and thirty-two cases of such perforating ulcers of the stomach were reported, of which one hundred and twenty-three recovered, a mortality of 48.81 per cent. In not a few of them, if prompt instead of late surgical help had been invoked, a very different result would have been reported. If no operation had been done, the mortality would have been one hundred per cent.

In cancer of the stomach itself we are able, as a rule, to make a positive diagnosis only when a perceptible tumor is found. By that time so many adhesions have formed, and the infection has involved the neighboring glands to such an extent, that it is impossible to remove the tumor, but the 256 statistics even here are not without encouragement, at least for comfort if not for life. In many cases the tumor has been removed and the stomach and intestine joined together by various devices, and the mortality, which is necessarily great, has been reduced by Czerny to twelve per cent. and by Carle to seven per cent. Even the entire stomach has been removed in several cases, and recovery has followed in about one-half. Most of these patients, however, have died from a return of the disease.

When, as a result of swallowing caustic lye or other similar substances, the gullet (the œsophagus) becomes contracted to such an extent that no food can be swallowed, we now establish an opening into the stomach through which a tube is inserted at meal-time, and the patient has his breakfast, dinner, and supper poured into his stomach through the tube. If the stricture of the œsophagus is from malignant disease, of course this only prolongs life by preventing a horrible death by starvation, but in cases in which it is non-malignant life is indefinitely prolonged. The mortality of such an operation is very small.

By a freak of nature or by disease the stomach sometimes is narrowed in the middle, forming what is called an “hour-glass stomach.” In such a case we open the abdomen, make an opening into the two parts of the stomach and unite the two so that we re-establish the single cavity of the stomach. The mortality of the operation is very slight, eight per cent. Again, sometimes the stomach becomes unduly dilated, thus interfering seriously with its function. A number of surgeons in such cases have simply folded over the wall of the stomach upon itself and have sewed the two layers together, taking a plait or “tuck” in the stomach wall, and have restored it to its normal capacity and function.

One of the most important advances has been made in the treatment of gall stones. The bile in the 257 gall bladder is in a state of quiescence, which is favorable to a deposit of crystals from the bile. These crystals become agglutinated together into larger or smaller solid masses called gall stones. Sometimes the number of these is very small, from one to four or five; sometimes they accumulate in enormous numbers, several hundreds having been reported in a number of instances. When they are small they can escape through the duct of the gall bladder into the bowel and create no disturbance, but when they are large, so that they cannot make their escape, they not uncommonly are causes not only of serious discomfort and prolonged ill-health, but often prove fatal. Nowadays one of the safest operations of surgery is to open the abdomen and the gall bladder and remove this menace to life, and the great majority of such patients recover without any untoward symptoms. Even large abscesses of the liver, and, what is still more extraordinary, large tumors of the liver, are now removed successfully. A year ago all of the reported cases of tumor of the liver were collected which had been operated from 1888 to 1898, seventy-six in all. The termination in two cases was unknown, but of the other seventy-four, sixty-three recovered and eleven died, a mortality of only 14.9 per cent.

The surgery of the intestines by itself is a subject which could well occupy the entire space allowed to this article. I can only, in a very superficial way, outline what has been done. Hernia or rupture is a condition in which through an opening in the abdominal wall a loop of the bowel escapes. If it can be replaced and kept within the abdomen by a suitable truss this was the best we could do till within the last ten or fifteen years. The safety and the painlessness of modern surgery which have resulted from the introduction of anæsthesia and antisepsis are such that now no person suffering from 258 such a hernia, unless for some special personal reason, should be allowed to rely upon a truss, which is always a more or less treacherous means of retaining the hernia. We operate on all such cases now with impunity. Coley has recently reported a series of six hundred and thirty-nine cases, all of which recovered with the exception of one patient. Even in children, if a truss worn for a reasonable time, a year or so, does not cure the rupture, operation affords an admirable prospect of cure.

Every now and then a band forms inside the abdomen, stretching like a string across the cavity. If a loop of bowel slips under such a band, it can be easily understood that total arrest of the intestinal contents ensues, a condition incompatible with life. There are other causes for such "intestinal obstruction," which are too technical to be described in detail, but this may be taken as a type of all. It is impossible, of course, to tell before opening the abdomen precisely the cause of the obstruction, but the fact is quickly determined in most cases. If we open the abdomen promptly, we can cut such a band or remove the other causes of obstruction in the majority of cases, and if the operation has not been too long delayed, the prospect of entire recovery is good. The mortality which has followed such operations has been considerable, and by that I mean, say, over twenty per cent., but a very large number of the fatal cases have been lost because the operation has been delayed. In fact, it may be stated very positively that the mere opening of the abdomen to find out precisely the nature of any disease or injury is attended with but little danger. If further surgical interference is required, the danger will be increased proportionately to the extent and gravity of such interference. But "exploratory operations," as we call them, are now undertaken constantly with almost uniform success.

Even in cancer of the bowel, we can prolong life, if we cannot save it. Cancer of the bowel sooner 259
or later produces "obstruction" and so destroys life, but in such cases we can either make a permanent opening in the bowel above the cancer, and so relieve the constant pain and distress which is caused by the obstruction, or, in a great many cases, we make an opening in the bowel above the cancer, and another below it, and, by uniting the two openings, if I may so express it, "side-track" the contents of the bowel. If the cancer has no adhesions and the patient's condition allows of it, we can cut out the entire portion of the bowel containing the cancer, unite the two ends, and thus re-establish the continuity of the intestinal canal. As much as eight feet, nearly one-third of the entire length of the bowel, have been removed by Shepherd, of Montreal, and yet the patient recovered and lived a healthy life.

Similarly in gun-shot wounds, stab wounds, etc., involving the intestine, the modern surgeon does not simply stand by with folded hands and give opium and morphine to make the patient's last few hours or days relatively comfortable, but he opens the abdomen, finds the various perforations, closes them, and recovery has followed even in cases in which as many as seventeen wounds of the intestine have been produced by a gun-shot wound.

The kidney, until thirty years ago, was deemed almost beyond our reach, but now entire volumes have been written on the surgery of the kidney, and it is, one might say, a frequent occurrence to see the kidney exposed, sewed fast if it is loose, opened to remove a stone in its interior, drained if there be an abscess, or, if it be hopelessly diseased, it is removed in its entirety. The other kidney, if not diseased, becomes equal to the work of both.

Of the pelvic organs, it would not be becoming to speak in detail, but one operation I can scarcely 260
omit: namely, ovariotomy. One of my old teachers was Washington L. Atlee, who, with his brother, was among the first ovariotomists in this country who placed the operation on a firm foundation. I heard a very distinguished physician in 1862, in a lecture to his medical class, denounce such men as "murderers"; but to-day how differently does the entire profession look upon the operation! Instead of condemning the surgeon because he did remove such a tumor, the profession would condemn him because he did not remove it. The operation had its rise in America. Ephraim McDowell, of Kentucky, in 1809, first did the operation which now reflects so much credit upon modern surgery. The mortality of the Atlees was about one in three. Now, owing to the immense improvement introduced by the antiseptic methods, the deaths, in competent hands, are not over five per cent., or even three per cent.

The limits of this article compel me to stop with the story very imperfectly told, but yet, perhaps, it has been sufficient in detail to show somewhat of the astonishing progress of surgery within the century, but especially within the last quarter of the century.

About two decades ago one of the foremost surgeons of London, Mr. Erichsen, said, in a public address, that "surgery had reached its limits." How short was his vision is shown by the fact that surgery at that time was just at the beginning of its most brilliant modern chapter.

We have reached, in many respects, apparently, the limits of our success, but just as anæsthesia and antisepsis and the Röntgen rays have opened new fields wholly unsuspected until they were proclaimed, so I have no doubt that the twentieth century will see means and methods devised which will put to shame the surgery of to-day as much as the surgery of to-day puts to shame that of thirty years ago, and still more of a century ago. The methods by which this will be attained will be by the [261] more thorough and systematic study of disease and injury, so as to better our means of diagnosis, and so prepare us for immediate surgical interference, instead of delaying it, as we now do in many cases, for want of certain knowledge; by the use of new chemical and pharmaceutical means to perfect our antisepsis and possibly to introduce other methods of treatment; but, above all, we shall obtain progress by the exact experimental methods of the laboratory. We can never make progress except by trying new methods. New methods must be tried either on man or on animals, and as the former is not allowable, the only way remaining to us is to test all new methods, drugs, and applications first upon animals. He who restricts, and, still more, he who would abolish our present experiments upon animals, is, in my opinion, the worst foe to the human race, and to animals, as well, for they, as well as human beings, obtain the benefit derived from the method. He may prate of his humanity, but he is the most cruel man alive.

W. W. Keen.

[265]

ELECTRICITY

The great importance which electricity has attained in many departments of human activity is so constantly evident that we have difficulty in realizing how short is the time which has been occupied in its development. The latter half of the nineteenth century must ever remain memorable, not only for the great advances in nearly all the useful arts, but for the peculiarly rapid electric progress, and the profound effect which it has had upon the lives and business of the people. In the preceding century we find no evidences of the application of electricity to any useful purpose. Few of the more important principles of the science were then known. Franklin's invention of the lightning-rod was not intended to utilize electric force, but to guard life and property from the perils of the thunder-storm. The numerous instructive experiments in frictional electricity, the first-known form of electric manifestation except lightning, made clear certain principles, such as conduction and insulation, and served to distinguish the two opposite electric conditions known as positive and negative. Franklin's kite experiment confirmed the long-suspected identity of lightning and electric sparks. It was not, however, until the discovery by Alexander Volta, in 1799, of his pile, or battery, that electricity could take its place as an agent of practical value. Volta, when he made this great discovery, was following the work of Galvani, begun in 1786. But Galvani in his experiments mistook the effect for the cause, and so missed making the unique demonstration that two different metals immersed in a solution could 266
set up an electric current. Volta, a professor in the University of Pavia and a foreign member of the Royal Society of England, communicated his discovery to the president of the society in March, 1800, and brought to the notice of the world the first means for obtaining a steady flow of electricity. Before this event electric energy had been known to the experimenter in pretty effects of attraction and repulsion of light objects, in fitful flashes of insignificant power, or, as it appeared in nature, in the fearful bursts of energy during a thunders-torm, uncontrolled and erratic. The analogous and closely related phenomena of magnetism had already found an important application in the navigator's compass.

The simplest facts of electro-magnetism, upon which much of the later electrical developments depend, remained entirely unknown until near the close of the first quarter of the nineteenth century. Magnetism itself, as exemplified in loadstone or in magnetized iron or steel, had long before been consistently studied by Dr. Gilbert, of Colchester, England, and in 1600 his great work, *De Magnete*, was published. It is a first example, and an excellent one, too, of the application of the inductive method, so fruitful in after-years. The restraints which a superstitious age had imposed upon nature study were gradually removed, and at the beginning of the century just past occasional decided encouragement began to be given to physical research. It was this condition which put into the hands of Humphry Davy, of the Royal Institution, in London, at the opening of the century, a voltaic battery of some 250 pairs of plates. With this a remarkably fruitful era of electric discovery began. In 1802 Davy first showed the electric arc or "arch" on a small scale between pieces of carbon. He also laid the 267
foundation for future electro-chemical work by decomposing by the battery current potash and soda, and thus isolating the alkali metals, potassium and sodium, for the first time. This was in 1807, and the result was not only to greatly advance the youthful science of chemistry, but to attract the attention of the world to a new power in the hands of the scientific worker, electric current. A fund was soon subscribed by "a few zealous cultivators and patrons of science," interested in the discovery of Davy, and he had at his service in 1801 no less than 2000 cells of voltaic battery. With the intense currents obtained from it he again demonstrated the wonderful and brilliant phenomenon of the electric arc, by first closing the circuit of the battery through terminals of hardwood charcoal and then separating them for a short distance. A magnificent arch of flame was maintained between the separated ends, and the light from the charcoal pieces was of dazzling splendor. Thus was born into the world the electric arc light, of which there are now many hundreds of thousands burning nightly in our own country alone.

Davy probably never imagined that his brilliant experiment would soon play so important a part in the future lighting of the world. He may never have regarded it as of any practical value. In fact, many years elapsed before any further attempt was made to utilize the light of the electric arc. The reason for this is not difficult to discover. The batteries in existence were crude and gave only their full power for a very short time after the circuit was closed. They were subject to the very serious defect of rapid polarization, whereby the activity was at once reduced. A long period elapsed before this defect was removed. Davy in his experiments had also noted the very intense heat of the electric arc, and found that but few substances escaped fusion or volatilization when placed in the heated stream between the 268
carbon electrodes. Here again he was pioneer in very important and quite recent electric work, employing the electric furnace, which has already given rise to several new and valuable industries.

The conduction of electricity along wires naturally led to efforts to employ it in signalling. As early as 1774 attempts were made by Le Sage, of Geneva, to apply frictional electricity to telegraphy. His work was followed before the close of the century by other similar proposals. Volta's discovery soon gave a renewed impetus to these efforts. It was easy enough to stop and start a current in a line of wire connecting two points, but something more than that was requisite. A good receiver, or means for recognizing the presence or absence of current in the wire or circuit, did not exist. The art had to wait for the discovery of the effects of electric current upon magnets and the production of magnetism by such currents. Curiously, even in 1802 the fact that a wire conveying a current would deflect a compass needle was observed by Romagnosi, of Trente, but it was afterwards forgotten, and not until 1819 was any real advance made.

It was then that Oersted, of Copenhagen, showed that a magnet tends to set itself at right angles to the wire conveying current and that the direction of turning depends on the direction of the current. The study of the magnetic effects of electric currents by Arago, Ampère, and the production of the electro-magnet by Sturgeon, together with the very valuable work of Henry and others, made possible the completion of the electric telegraph. This was done by Morse and Vail in America, and almost simultaneously by workers abroad, but, before Morse had entered the field, Professor Joseph Henry had exemplified by experiments the working of electric signalling by electro-magnets over a short line. It was Henry, in fact, who first made a practically useful electro-magnet of soft iron. The history of the 269
electric telegraph teaches us that to no single individual is the invention due. The Morse system had been demonstrated in 1837, but not until 1844 was the first telegraph line built. It connected Baltimore and Washington, and the funds for defraying its cost were only obtained from Congress after a severe struggle. This can easily be understood, for electricity had not up to that time ever been shown to have any practical usefulness. The success of the Morse telegraph was soon followed by the establishment of telegraph lines as a means of communication between all the large cities and populous districts. Scarcely ten years elapsed before the possibility of a transatlantic telegraph was mooted. The cable laid in 1858 was a failure. A few words passed, and then the cable broke down completely. This was found to be due to defects in construction. A renewed effort to lay a cable was made in 1866, but disappointment again followed: the cable broke in mid-ocean and the work again ceased. The great task was successfully accomplished in the following year, and the pluck and pertinacity of those who were staking their capital, if not their reputations for business sagacity, were amply rewarded. Even the lost cable of 1866 was found, spliced to a new cable, and completed soon after as a second working line. The delicate instruments for the working of these long cables were due to the genius of Sir William Thomson, now Lord Kelvin, whose other instruments for electrical measurement have for years been a great factor in securing precision both in scientific and practical testing. The number of cables joining the Eastern and Western hemispheres has been increased from time to time, and the opening of a new cable is now an ordinary occurrence, calling for little or no especial note.

The introduction of the electric telegraph was followed by the invention of various signalling 270
systems, the most important being the fire-alarm telegraph, as suggested by Channing and worked out by Farmer. We now, also, have automatic clock systems, in which a master clock controls or gives movement to the hands of distant clock dials by electric currents sent out over the connecting or circuit wires. Automatic electric signals are made when fire breaks out in a building, and alarms are similarly rung when a burglar breaks in. Not only do we have telegraphs which print words and characters, as in the stock "ticker," but in the form known as the telautograph, invented by Dr. Elisha Gray, the sender

writes his message, which writing is at the same time being reproduced at the receiving end of the line. Even pictures for drawings are "wired" by special instruments. The desirability of making one wire connecting two points do a large amount of work, and thus avoiding the addition of new lines, has led to two remarkable developments of telegraphy. In the duplex, quadruplex, and multiplex systems several messages may at the same time be traversing a single wire line without interference one with the other. In the rapid automatic systems the working capacity of the line is increased by special automatic transmitting machines and rapid recorders, and the electric impulses in the line itself follow each other with great speed.

Improvement in this field has by no means ceased, and new systems for rapid transmission are yet being worked out. The object is to enlarge the carrying capacity of existing lines connecting large centres of population. The names of Wheatstone, Stearns, Edison, and Delaney are prominent in connection with this work. For use in telegraphy the originally crude forms of voltaic battery, such as Davy used, were replaced by the more perfect types such as the constant battery of Daniell, the nitric- 271
acid battery of Grove, dating from 1836, and the carbon battery of Bunsen, first brought out in 1842. Such was the power of the Grove and Bunsen batteries that attention was again called to the electric arc and to the possibility of its use for electric illumination. Accordingly, we find that suggestions were soon made for electric-arc lamps, to be operated by these more powerful and constant sources of electric current. The first example of a working type of an arc lamp was that brought to notice by W. E. Staite, in 1847, and his description of the lamp and the conditions under which it could be worked is a remarkably exact and full statement, considering the time of its appearance. Staite even anticipated the most recent phase of development in arc lighting, namely, the enclosure of the light in a partially air-tight globe, to prevent too rapid waste of the carbons by combustion in the air. In a public address at Newcastle-on-Tyne, in 1847, he advocated the use of the arc, so enclosed, in mines, as obviating the danger of fire. But it was a long time before the electric arc acquired any importance as a practical illuminant. There was, indeed, no hope of its success so long as the current had to be obtained from batteries consuming chemicals and zinc. The expense was too great, and the batteries soon became exhausted. In spite of this fact, occasional exhibitions of arc lighting were made, notably in 1856, by Lacassagne and Thiers, in the streets of Paris.

For this service they had invented an arc lamp involving what is known as the differential principle, afterwards applied so extensively to arc lamps. The length of the arc or the distance between the carbons of the lamp was controlled with great nicety, and the light thus rendered very steady. Even as late as 1875 batteries were occasionally used to work single electric arc lamps for public exhibitions, or for demonstration purposes in the scientific departments of schools. The discovery of 272
the means of efficiently generating electricity from mechanical power constitutes, however, the key-note of all the wonderful electrical work of the closing years of the nineteenth century. It made electrical energy available at low cost. Michael Faraday, a most worthy successor of Davy at the Royal Institution, in studying the relations between electric currents and magnets, made the exceedingly important observation that a wire, if moved in the field of a magnet, would yield a current of electricity. Simple as the discovery was, its effect has been stupendous. Following his science for its own sake, he unwittingly opened up possibilities of the greatest practical moment. The fundamental principle of the future dynamo electric machine was discovered by him. This was in 1831. Faraday's investigations were so complete and his deductions so masterly, that little was left to be done by others. Electro-magnetism was supplemented by magneto-electricity. Both the electric motor and the dynamo generator were now potentially present with us. Faraday contented himself with pointing the way, leaving the technical engineer to follow. In one of Faraday's experiments a copper disk mounted on an axis passing through its centre was revolved between the poles of a large steel magnet. A wire touched the periphery of the disk at a selected position with respect to the magnet, and another was in connection with the axis. These wires were united through a galvanometer or instrument for detecting electric current. A current was noted as present in the circuit so long as the disk was turned. Here, then, was the embryo dynamo. The century closed with single dynamo machines of over 5000 horse-power capacity, and with single power stations in which the total electric generation by such machines is 75,000 to 100,000 horse-power. So perfect is the modern dynamo that out of 1000 horse-power 273
expended in driving it, 950 or more may be delivered to the electric line as electric energy. The electric

motor, now so common, is a machine like the dynamo, in which the principle of action is simply reversed; electric energy delivered from the lines becomes again mechanical motion or power.

Soon after Faraday's discoveries in magneto-electricity attempts were made to construct generators of electricity from power. But the machines were small, crude, and imperfect, and the results necessarily meagre.

Pixii, in Paris, one year after Faraday's discovery was announced, made a machine which embodied in its construction a simple commutator for giving the currents a single direction of flow. This is the prototype of the commutators now found on what are called continuous-current dynamos. After Pixii followed Saxton, Clarke, Wheatstone and Cooke, Estohrer, and others, but not until 1854 was any very notable improvement made or suggested. In that year Soren Hjorth, of Copenhagen, described in a patent specification the principle of causing the electric currents generated to traverse coils of wire so disposed as to reinforce the magnetic field of the machine itself. A year subsequently the same idea was again more clearly set out by Hjorth. This is the principle of the modern self-exciting dynamo, the field magnets of which, very weak at the start, are built up or strengthened by the currents from the armature or revolving part of the machine in which power is consumed to produce electricity.

In 1856 Dr. Werner Siemens, of Berlin, well known as a great pioneer in the electric arts, brought out the Siemens armature, an innovation more valuable than any other made up to that time. This was subsequently used in the powerful machines of Wilde and Ladd. It still survives in magneto call-bell apparatus for such work as telephone signalling, in exploders for mines and blasting, and in the 274
simpler types of electroplating dynamos.

The decade between 1860 and 1870 opened a new era in the construction and working of dynamo machines and motors. It is notable for two advances of very great value and importance. Dr. Paccinotti, of Florence, in 1860, described a machine by which true continuous currents resembling battery currents could be obtained. Up to that time machines gave either rapidly alternating or fluctuating currents, not steady currents in one direction. The Paccinotti construction, in modified forms, is now almost universally employed in dynamo machines, and even where the form is now quite different the Paccinotti type has been at least the forerunner, and has undergone modifications to suit special ends in view. Briefly, Paccinotti made his armature of a ring of iron with iron projections between which the coils of insulated wire were wound. Although full descriptions of Paccinotti's ring armature and commutator were given out in 1864, his work attracted but little attention until Gramme, in Paris, about 1870, brought out the relatively perfect Gramme machine. In the mean time the other great development of the decade took place.

Although Hjorth had, as stated before, put forward the idea that a dynamo generator might itself furnish currents for magnetizing its own magnets, this valuable suggestion was not apparently worked out until 1866, when a machine was constructed for Sir Charles Wheatstone. This appears to have been the first self-exciting machine in existence. Wheatstone read a paper before the Royal Society in February, 1867, "On the Augmentation of the Power of a Magnet by the Reaction thereon of Currents Induced by the Magnet Itself." This action later became known as the reaction principle in dynamo machines.

As often happens, the idea occurred to other workers in science almost simultaneously, and Dr. 275
Werner Siemens also read a paper in Berlin about a month earlier than that of Wheatstone, clearly describing the reaction principle. Furthermore, a patent specification had been filed in the British Patent Office by S. A. Varley, December 24, 1866, clearly showing the same principle of action, and he was, therefore, the first to put the matter on record. The time was ripe for the appearance of machines closely resembling the types now in such extended use. Gramme, in 1870, adopting a modified form of the Paccinotti ring and commutator, and employing the reaction principle, first succeeded in producing a highly efficient, compact, and durable continuous-current dynamo. The Gramme machine was immediately recognized as a great technical triumph. It was in a sense the culmination of many years of development, beginning with the early attempts immediately following Faraday's discovery, already referred to. Gramme constructed his revolving armature of a soft iron

wire ring, upon which ring a series of small coils of insulated wire were wound in successive radial planes. These coils were all connected with a continuous wire and from the junctions of the coils one with another connections were taken to a range of copper bars insulated from each other, constituting the commutator. In 1872 Von Hefner Alteneck, in Berlin, modified the ring winding of Gramme and produced the "drum winding," which avoided the necessity for threading wire through the centre of the iron ring as in the Gramme construction. The several coils of the drum were still connected, as in Gramme's machine, to the successive strips of the commutator.

In modern dynamos and motors the armature, usually constructed of sheet-iron punchings, is a ring with projections as in Paccinotti's machine, and the coils of wire are in most cases wound 276 separately and then placed in the spaces between the projections, constituting in fact a form of drum winding. In the early 70's a few Gramme ring and Siemens drum machines had been applied to the running of arc lights, one machine for each light. There were also some Gramme machines in use for electroplating.

At the Centennial Exhibition, held at Philadelphia in 1876, but two exhibits of electric-lighting apparatus were to be found. Of these one was the Gramme and the other the Wallace-Farmer exhibit. The Wallace-Farmer dynamo machine is a type now obsolete. It was not a good design, but the Wallace exhibit contained other examples reflecting great credit on this American pioneer in dynamo work. Some of these machines were very similar in construction to later forms which went into very extensive use. The large search-lights occasionally used in night illumination during the exhibitions were operated by the current from Wallace-Farmer machines. The Gramme exhibit was a remarkable exhibit for its time. Though not extensive, it was most instructive. There were found in it a dynamo running an arc lamp; a large machine for electrolytic work, such as electroplating or electrotyping, and, most novel and interesting of all, one Gramme machine driven by power was connected to another by a pair of wires and the second run as a motor. This in turn drove a centrifugal-pump, and raised water which flowed in a small fall or cataract. A year or two previously the Gramme machine had been accidentally found to be as excellent an electric motor as it was a generating dynamo. The crude motors of Jacobi, Froment, Davenport, Page, Vergnes, Gaume, and many others, were thus rendered obsolete at a stroke. The first public demonstration of the working of one Gramme machine by another was made by Fontaine at the Vienna Exhibition of 1873. 277

Here, then, was a foreshadowing of the great electric-power transmission plants of to-day; the suggestion of the electric station furnishing power as well as light, and, to a less degree, the promise of future railways using electric power. Replace the centrifugal pump of this modest exhibit by a turbine wheel, reverse the flow of water so as to cause it to drive the electric motor so that the machine becomes a dynamo, and, in like manner, make of the dynamo a motor, and we exemplify in a simple way recent great enterprises using water-power for the generation of current to be transmitted over lines to distant electric motors or lights.

The Centennial Exhibition also marks the beginning—the very birth, it may be said—of an electric invention destined to become, before the close of the century, a most potent factor in human affairs. The speaking telephone of Alexander Graham Bell was there exhibited for the first time to the savants, among whom was the distinguished electrician and scientist Sir William Thomson. For the first time in the history of the world a structure of copper wire and iron spoke to a listening ear. Nay, more, it both listened to the voice of the speaker and repeated the voice at a far-distant point. The instruments were, moreover, the acme of simplicity. Within a year many a boy had constructed a pair of telephones at an expenditure for material of only a few pennies. In its first form the transmitting telephone was the counterpart of the receiver, and they were reversible in function. The transmitter was in reality a minute dynamo driven by the aërial voice waves; the receiver, a vibratory motor worked by the vibratory currents from the transmitter and reproducing the aërial motions. This arrangement, most beautiful in theory, was only suited for use on short lines, and was soon afterwards 278 replaced by various forms of carbon microphone transmitter, to the production of which many inventors had turned their attention, notably Edison, Hughes, Blake, and Hunnings. In modern transmitters the voice wave does not furnish the power to generate the telephone current, but only controls the flow of an already existing current from a battery. In this way the effects obtainable may be made sufficiently powerful for transmission to listeners 1500 miles away.

There is no need to dwell here upon the enormous saving of time secured by the telephone and the profound effect its introduction has had upon business and social life. The situation is too palpable. Nevertheless, few users of this wonderful invention realize how much thought and skill have been employed in working out the details of exchange switchboards, of signalling devices, of underground cables and overhead wires, and of the speaking instruments themselves. Few of those who talk between Boston and Chicago know that in doing so they have for the exclusive use of their voices a total of over 1,000,000 pounds of copper wire in the single line. There probably now exist in the United States alone between 75,000 and 100,000 miles of hard-drawn copper wire for long-distance telephone service, and over 150,000 miles of wire in underground conduits. There are upward of three-quarters of a million telephones in the United States, and, including both overhead and underground lines, a total of more than half a million miles of wire. Approximately one thousand million conversations are annually conveyed.

The possibility of sub-oceanic telephoning is frequently discussed, but the problem thus far is not solved. It involves grave difficulties, and we may hope that its solution is to be one of the advances which will mark the twentieth century's progress.

The advent of the telephone in 1876 seemed to stimulate invention in the electric field to a 279 remarkable degree. Its immediate commercial success probably acted also to inspire confidence in other proposed electric enterprises. Greater attention than ever before began to be given to the problem of electric lighting. An electric arc lamp, probably the only one in regular use, had been installed at Dungeness Light-house in 1862, after a long set of trials and tests. It was fed by a Holmes magneto-electric machine of the old type, very large and cumbrous for the work. Numerous changes and improvements had before 1878 been made in arc lamps by Serrin, Duboscq, and many others. But the display of electric light during the Paris Exposition of 1878 was the first memorable use of the electric light on a large scale. The splendid illumination of the Avenue de l'Opéra was a grand object-lesson. The source of light was the "electric candle" of Paul Jablochkoff, a Russian engineer. It was a strikingly original and simple arc lamp. Instead of placing the two carbons point to point, as had been done in nearly all previous lamps, he placed them side by side, with a strip of baked kaolin between them. The candle so formed was supported in a suitable holder, whereby, at the lower end, the two parallel carbons were connected with the circuit terminals. By a suitable device the arc was started at the top and burned down. The electric candle seemed to solve the problem of allowing complicated mechanism for feeding the carbons to be discarded; but it survived only a short time. Owing to unforeseen difficulties it was gradually abandoned, after having served a great purpose in directing the attention of the world to the possibilities of the electric arc in lighting.

Inventors in America were not idle. By the close of 1878, Brush, of Cleveland, had brought out his series system of arc lights, including special dynamos, lamps, etc., and by the middle of 1879 had in operation machines each capable of maintaining sixteen arc lamps on one wire. This was, indeed, a 280 great achievement for that time. Weston, of Newark, had also in operation circuits of arc lamps, and the Thomson-Houston system had just started in commercial work with eight arc lamps in series from a single dynamo. Maxim and Fuller, in New York, were working arc lamps from their machines, and capital was being rapidly invested in new enterprises for electric lighting. Some of the great electric manufacturing concerns of to-day had their beginning at that time. Central lighting stations began to be established in cities, and the use of arc lights in street illumination and in stores grew rapidly. More perfect forms of arc lamps were invented, better generating dynamos and regulating apparatus brought out. Factories for arc-light carbon making were built. The first special electrical exhibition was held in Paris in 1881. In the early 80's, also, the business of arc lighting had become firmly established, and soon the bulk of the work was done under two of the leading systems. These were afterwards brought together under one control, thus securing in the apparatus manufactured a combination of the good features of both. Until about 1892 nearly all the arc lamps in use were worked under the series system, in which the lights are connected one after another on a circuit and traversed by the same current. This current has a standard value, or is a constant current. Sometimes as many as a hundred lamps were on one wire. As the mains for the supply of incandescent lamps at constant pressure, or potential, were extended, attention was more strongly turned to the possibility of working arc lights therefrom.

Within a few years of the close of the century this placing of arc lamps in branches from the same mains which supply incandescent lamps became common, and the enclosure of the arc in a partially air-tight globe, a procedure advocated by Staite, in 1847, was revived by Howard, Marks, and others 281
for saving carbons and attention to the lamp. The enclosed arc lamp was also found to be especially adapted to use in branches of the incandescent lamp circuits, which had in cities become greatly extended. The increasing employment of alternating currents in the distribution of electric energy has led also to the use of alternating current arc lamps, and special current-regulating apparatus is now being applied on a large scale to extended circuits of these lamps. It can be seen from these facts that the art is still rapidly progressing and the field ever widening. A little over twenty years ago practically no arc lamps were used. At the close of the century, they were numbered by hundreds of thousands. The annual consumption of carbons in this country has reached two hundred millions.

Almost simultaneously with the beginning of the commercial work of arc lighting, Edison, in a successful effort to provide a small electric lamp for general distribution in place of gas, brought to public notice his carbon filament incandescent lamp.

A considerable amount of progress had previously been made by various workers in attempting to reduce the volume of light in each lamp and increase the number of lights for a given power expended. Forms of incandescent arc lamps, or semi-incandescent lamps, were tried on a considerable scale abroad, but none have survived. So, also, many attempts to produce a lamp giving light by pure incandescence of solid conductors proved for the most part abortive. Edison himself worked for nearly two years on a lamp based upon the old idea of incandescent platinum strips or wires, but without success. The announcement of this lamp caused a heavy drop in gas shares, long before the problem was really solved by a masterly stroke in his carbon filament lamp. Curiously, the nearest approach to 282
the carbon filament lamp had been made in 1845, by Starr, an American, who described in a British patent specification a lamp in which electric current passed through a thin strip of carbon kept it heated while surrounded by a glass bulb in which a vacuum was maintained. Starr had exhibited his lamps to Faraday, in England, and was preparing to construct dynamos to furnish electric current for them in place of batteries, but sudden death put an end to his labors. The specification describing his lamp is perhaps the earliest description of an incandescent lamp of any promise, and the subsequently recorded ideas of inventors up to the work of Edison seem now to be almost in the nature of retrograde movements. None of them were successful commercially. Starr, who was only twenty-five years of age, is reported to have died of overwork and worry in his efforts to perfect his invention. His ideas were evidently far in advance of his time.

The Edison lamp differed from those which preceded it in the extremely small section of the carbon strip rendered hot by the current, and in the perfection of the vacuum in which it was mounted. The filament was first made of carbonized paper, and afterwards of bamboo carbon. The modern incandescent lamp has for years past been provided with a filament made by a chemical process. The carbon formed is exceedingly homogeneous and of uniform electric resistance. Edison first exhibited his lamp in his laboratory at Menlo Park, New Jersey, in December, 1879; but before it could be properly utilized an enormous amount of work had to be done. His task was not merely the improvement of an art already existing; it was the creation of a new art. Special dynamo machines had to be invented and constructed for working the lamps; switches were needed for connecting and disconnecting lamps and groups of lamps; meters for measuring the consumption of electric energy 283
were wanted; safety fuses and cut-offs had to be provided; electroliers or fixtures to support the lamp were required; and, lastly, a complete system of underground mains with appurtenances was a requisite for city plants.

Even the steam-engines for driving the dynamos had to be remodelled and improved for electric work, and ten years of electric lighting development did more towards the refinement and perfection of steam-engines than fifty years preceding. Steadiness of lights meant the preservation of steady speed in the driving machinery. The Pearl Street station in New York City was the first installation for the supply of current for incandescent lighting in a city district. The constant pressure dynamos were gradually improved and enlarged. The details of all parts of the system were made more perfect, and in the hands of Edison and others the incandescent lamps, originally of high cost, were much cheapened and the quality of the production was greatly improved. Lamps originally cost one dollar each. The best lamps that are made can be had at present for about one-fifth that price. Millions of incandescent lamps are annually manufactured. Great lighting stations furnish the current for the working of these lamps, some stations containing machinery aggregating many thousands of horse-power capacity. Not only do these stations furnish electric energy for the working of arc lamps and incandescent lamps, but, in addition, for innumerable motors ranging in size from the small desk fan of one-tenth horse-power up to those of hundreds of horse-power. The larger sizes replace steam or hydraulic power for elevators, and many are used in shops and factories for driving machinery such as printing-presses, machinery tools, and the like.

In spite of the fact that it was well known that a good dynamo when reversed could be made a source of power, few electric motors were in use until a considerable time after the establishment of 284
the first lighting stations. Even in 1884, at the Philadelphia Electrical Exhibition, only a few electric motors were shown. Not until 1886 or thereafter did the "motor load" of an electric station begin to be a factor in its business success. The motors supplied are an advantageous adjunct, inasmuch as they provide a day load, increasing the output of the station at a time when the lighting load is small and when the machinery in consequence would, without them, have remained idle. The growth of the application of electric motors in the closing years of the century has been phenomenal, even leaving out of consideration their use in electric railways.

Twenty years ago an electric motor was a curiosity; fifty years ago crude examples run by batteries were only to be occasionally found in cabinets of scientific apparatus. Machinery Hall, at the Centennial Exhibition of 1876, typified the mill of the past, never again to be reproduced, with its huge engine and lines of heavy shafting and belts conveying power to the different tools or machines in operation. The modern mill or factory has its engines and dynamos located wherever convenient, its electric lines and numerous motors connected thereto, and each of them either driving comparatively short lines of shafting or attached to drive single pieces of machinery. The wilderness of belts and pulleys which used to characterize a factory is gradually being cleared away, and electric distribution of power substituted. Moreover, the lighting of the modern mill or factory is done from the same electric plant which distributes power.

The electric motor has already partly revolutionized the distribution of power for stationary machinery, but as applied to railways in place of animal power the revolution is complete. The period which has elapsed since the first introduction of electric railways is barely a dozen years. It is true that 285
a few tentative experiments in electric traction were made some time in advance of 1888, notably by Siemens, in Berlin, in 1879 and 1880, by Stephen D. Field, by T. A. Edison, at Menlo Park, by J. C. Henry, by Charles A. Van Depoele, and others. If we look farther back we find efforts such as that of Farmer, in 1847, to propel railway cars by electric motors driven by currents from batteries carried on the cars. These efforts were, of course, doomed to failure, for economical reasons. Electric energy from primary batteries was too costly, and if it had been cheaper, the types of electric motor used yielded so small a return of power for the electric energy spent in driving them that commercial success was out of the question. These early efforts were, however, instructive, and may now be regarded as highly suggestive of later work. Traction by the use of storage batteries carried on an electric car has been tried repeatedly, but appears not to be able to compete with systems of direct supply from electric lines. The plan survives, however, in the electric automobile, many of which have been put into service within a year or two. The electric automobile is not well fitted for country touring; it is best adapted to cities, where facilities for charging and caring for the batteries can be had. Moreover, the electric carriage is of all automobile carriages the most easily controlled, most ready; it emits no smell or hot gases and is nearly noiseless.

About 1850, Hall, a well-known instrument maker of Boston, catalogued a small toy electric locomotive dragging a car upon rails which were insulated and connected with a stationary battery of two Grove cells. This arrangement was sold as a piece of scientific apparatus, and appears to be the first example of an electrically driven vehicle connected by rolling contacts to an immovable energy source. Other early experimenters, such as Siemens, Field, and Daft, subsequently to Hall, used in actual railway work the supply by insulated tracks. This was supplanted later by overhead insulated wires or by the insulated third rail. Siemens & Halske, of Berlin, used a special form of overhead supply in 1881, and during the electrical exhibition in Paris in that year, a street tramway line was run by them. Later, Edison experimented with a third-rail-supply line at Menlo Park; and at Portrush, in Ireland, an actual railway was put in operation by Siemens & Halske, using the third-rail system. This was about 1883. The power of the Portrush railway was that of a water-wheel driving the generating dynamo. 286

The modern overhead trolley, or under-running trolley, as it is called, seems to have been first invented by Van Depoele, and used by him in practical electric railway work about 1886 and thereafter. The universality of this invention for overhead supply marks the device as a really important advance in the art of electric traction. Van Depoele was also a pioneer in the use of an underground conduit, which he employed successfully in Toronto in 1884. The names of Edward M. Bentley and Walter H. Knight stand out prominently in connection with the first use of an underground conduit, tried under their plans in August, 1884, at Cleveland, on the tracks of the horse-railway company.

We have barely outlined the history of the electric-motor railway up to the beginning of a period of wonderful development, resulting in the almost complete replacement by electric traction of horse traction or tramway lines, all within an interval of scarcely more than ten years.

The year 1888 may be said to mark the beginning of this work, and in that year the Sprague Company, with Frank J. Sprague at its head, put into operation the electric line at Richmond, Virginia, using the under-running trolley. Mr. Sprague had been associated with Edison in early traction work, 287 and was well known in connection with electric-motor work in general. The Richmond line was the first large undertaking. It had about thirteen miles of track, numerous curves, and grades of from three to ten per cent. The enterprise was one of great hardihood, and but for ample financial backing and determination to spare no effort or expenditure conducive to success, must certainly have failed. The motors were too small for the work, and there had not been found any proper substitute for the metal commutator brushes on the motors—a source of endless trouble and of an enormous expense for repairs. Nevertheless, the Richmond installation, kept in operation as it was in spite of all difficulties, served as an object-lesson, and had the effect of convincing Mr. Henry M. Whitney and the directors of the West End Street Railway, of Boston, of the feasibility of equipping the entire railway system of Boston electrically. Meanwhile the merging of the Van Depoele and Bentley-Knight interests into the Thomson-Houston Electric Light Company brought a new factor into the field, the Sprague interests being likewise merged with the Edison General Electric Company.

The West End Company, with two hundred miles of track in and around Boston, began to equip its lines in 1888 with the Thomson-Houston plant. The success of this great undertaking left no doubt of the future of electric traction. The difficulties which had seriously threatened future success were gradually removed.

The electric railway progress was so great in the United States that about January 1, 1891, there were more than two hundred and forty lines in operation. About thirty thousand horses and mules were replaced by electric power in the single year of 1891. In 1892 the Thomson-Houston interests and those of the Edison General Electric Company were merged in the General Electric Company, an event 288 of unusual importance, as it brought together the two great competitors in electric traction at that date. Other electric manufacturers, chief among which was the Westinghouse Company, also entered the field and became prominent factors in railway extension. In a few years horse traction in the United States on tramway lines virtually disappeared. Many cable lines were converted to electric lines, and projects such as the Boston Subway began to be planned. Not the least of the advantages of electric traction is the higher speed attainable with safety. The comfort and cleanliness of the cars, lighted brilliantly at night, and heated in winter by the same source of energy which is used to propel them, are important factors.

All these things, together with the great extension of the lines into suburban and country districts, and the interconnection of the lines of one district with those of another, cannot fail to have a decidedly beneficial effect upon the life, habits, and health of the people. While the United States and Canada have been and still are the theatre of the enormous advance in electric traction, as in other electric work, many electric car lines have in recent years been established in Great Britain and on the continent of Europe. Countries like Japan, Australia, South Africa, and South America have also in operation many electric trolley lines, and the work is rapidly extending. Most of this work, even in Europe, has been carried out either by importation of equipment from America, or by apparatus manufactured there, but following American practice closely. The bulk of the work has been done with the overhead wire and under-running trolley, but there are notable instances of the use of electric conductors in underground slotted conduits, chief of which are the great systems of street railway in New York City.

In Chicago the application of motor-cars in trains upon the elevated railway followed directly 289 upon the practical demonstration at the World’s Fair of the capabilities of third-rail electric traction on the Intramural Elevated Railway, and the system is rapidly extending so as to include all elevated city roads. A few years will doubtless see the great change accomplished.

The motor-car, or car propelled by its own motors, has also been introduced upon standard steam roads to a limited extent as a supplement to steam traction. The earliest of these installations are the one at Nantasket, Massachusetts, and that between Hartford and New Britain, in Connecticut. A number of special high-speed lines, using similar plans, have gone into operation in recent years. The problem of constructing electric motors of sufficient robustness for heavy work and controlling them effectively was not an easy one, and the difficulties were increased greatly because of the placing of the motors under the car body, exposed to wet, to dust and dirt of road. The advantage of the motor-car, or motor-car train, is that the traction or hold upon the track increases with the increase of the weight or load carried. It is thus able to be accelerated rapidly after a stop, and also climb steep grades without slipping its wheels. Nevertheless, there are circumstances which favor the employment of a locomotive at the head of a train, as in steam practice. This is the case in lines where a train of coal or ore cars is drawn by electric mining locomotives. Many such plants are in operation, and, at the same time the electric power is used to drive fans for ventilating, pumps for drainage, electric hoists, etc., besides being used for lighting the mines. The trains in the tunnels of the Metropolitan Underground Railway of London have for many years been operated by steam locomotives with the inevitable escape of steam, foul, suffocating gases, and more or less soot.

A number of years ago the tunnel of the City and South London Railway was put into successful 290 operation with electric locomotives drawing the trains of cars, and the nuisance caused by steam avoided. This work recalls the early efforts of Field, of Daft, and Bentley and Knight in providing an electric locomotive for replacing the steam plant of the elevated roads in New York City. Well-conceived as many of these plans were, electric traction had not reached a sufficient development, and the efforts were abandoned after several more or less successful trials. It is now seen that the motor-car train may advantageously replace the locomotive-drawn train in such instances as these elevated railways.

The three largest and most powerful electric locomotives ever put into service are those which are employed to take trains through the Baltimore and Ohio Railroad tunnel at Baltimore. They have been in service about seven or eight years, and are fully equal in power to the large steam locomotives used on steam roads. Frequently trains of cars, including the steam locomotive itself, are drawn through the tunnel by these huge electric engines, the fires on the steam machines being for the time checked so as to prevent fouling the air of the tunnel. There was opened, in London, in 1900, a new railway called the Central Underground, equipped with twenty-six electric locomotives for drawing its trains. The electric and power equipment, which embodied in itself the latest results of American practice, was also manufactured in America to suit the needs of the road. Other similar railways are in contemplation in London and in other cities of Europe. As on the elevated roads in New York City, the replacement of underground steam traction, where it exists, by electric traction is evidently only a question of a few years.

An electric railway may exemplify a power-transmission system in which power is delivered to moving vehicles. But the distances so covered are not generally more than a few miles from the generating station. Where, however, abundant water-power exists, as at Niagara, or where fuel is very expensive and power is to be had only at great distances from the place at which it is to be used, electricity furnishes the most effective means for transmission and distribution. Between the years 1880 and 1890 the device called alternating current transformer was developed to a considerable degree of perfection. It is, in reality, a modified induction coil, consisting of copper wire and iron, whereby a current sent through one of its coils will induce similar currents in the other coils of apparatus. It has the great advantage of having no moving parts. Faraday, in 1831, discovered the fundamental principle of the modern transformer. Not only, however, will the current in one coil of the apparatus generate by induction a new current in an entirely separate coil or circuit, but by suitably proportioning the windings we may exchange, as it were, a large low-pressure current for a small but high-pressure current, or *vice versa*. This exchange may be made with a very small percentage of loss of energy. These valuable properties of the transformer have rendered it of supreme importance in recent electrical extension. The first use made of it, in 1885–86, was to transform a high-pressure current into one of low pressure in electric lighting, enabling a small wire to be used to convey electric energy at high pressure, and without much loss, to a long distance from the station. This energy at high pressure reaches the transformer placed within or close to the building to be lighted. A low-pressure safe current is conveyed from the transformer to the wires connected to the lamps. In this way a current of two thousand volts, an unsafe and unsuitable pressure for incandescent lighting, is exchanged for one of about one hundred volts, which is quite safe. In this way, also, the supply station is enabled to reach a customer too far away to be supplied directly with current at one hundred volts, without enormous expense for copper conductors. 291 292

The alternating current transformer not only greatly extended the radius of supply from a single station, but also enabled the station to be conveniently located where water and coal could be had without difficulty. It also permitted the distant water-powers to become sources of electric energy for lighting, power, or for other service. For example, a water-power located at a distance of fifty to one hundred miles or more from a city, or from a large manufacturing centre where cost of fuel is high, may be utilized as follows: A power-station will be located upon the site of the water-power, and the dynamos therein will generate electricity at, say, two thousand volts pressure. By means of step-up transformers this will be exchanged for a current of thirty thousand volts for transmission over a line of copper or aluminum wire to the distant consumption area. Here there will be a set of step-down transformers which will exchange the thirty-thousand-volt line current for one of so low a pressure as to be safe for local distribution to lamps, to motors, etc., either stationary or upon a railway. The same transmission plant may simultaneously supply energy for lighting, for power, for heat, and for charging storage batteries. It may, therefore, be employed both day and night.

These long-distance power transmission plants are generally spoken of as “two-phase,” “three-phase,” or “polyphase” systems. Before 1890 no such plants existed. A large number of such installations are now working over distances of a few miles up to one hundred miles. They differ from what are known as single-phase alternating systems in employing, instead of a single alternating current, two, three, or more, which are sent over separate lines, and in which the electric impulses are not simultaneous, but follow each other in regular succession, overlapping each other’s dead points, so to speak. Early suggestions of such a plan, about 1880, and thereafter, by Bailey, Deprez, and others, bore no fruit, and not until Tesla’s announcement of his polyphase system, in 1888, was much attention given to the subject. A widespread interest in Tesla’s work was invoked, but several years elapsed before engineering difficulties were overcome. This work was done mainly by the technical staffs of the large manufacturing companies, and it was necessary to be done before any notable power transmissions on the polyphase system could be established. After 1892 the growth became very rapid. 293

The falls of Niagara early attracted the attention of engineers to the possibility of utilizing at least a fraction of the power. It was seen that several hundred thousand horse-power might be drawn from it without materially affecting the fall, itself equivalent to several millions of horse-power. A gigantic power-station has lately been established at Niagara, taking water from a distance above the falls and delivering it below the falls through a long tunnel which forms the tail race. Ten water-wheels, located

in an immense wheel-pit about two hundred feet deep, each wheel of a capacity of five thousand horse-power, drive large vertical shafts, at the upper end of which are located the large two-phase dynamos, each of five thousand horse-power. The electric energy from these machines is in part raised in pressure by huge transformers for transmission to distant points, such as the city of Buffalo, and a large portion is delivered to the numerous manufacturing plants located at moderate distances from the power-station. Besides the supply of energy for lighting, and for motors, including railways, other recent uses of electricity to which we have not yet alluded are splendidly exemplified at Niagara. 294
Davy's brilliant discovery of the alkali metals, sodium and potassium, at the opening of the century, showed the great chemical energy of the electric current. Its actions were afterwards carefully studied, notably by the illustrious Faraday, whose discoveries in connection with magnetism and magneto-electricity have been briefly described. The electric current was found to act as a most potent chemical force, decomposing and recomposing many chemical compounds, dissolving and depositing metals. Hence, early in the century arose the art of electroplating of metals, such as electro-gilding, silver-plating, nickel-plating, and copper deposition as in electrotyping. These arts are now practised on a very large scale, and naturally have affected the whole course of manufacturing methods during the century. Moreover, since the introduction of dynamo current, electrolysis has come to be employed in huge plants, not only for separating metals from each other, as in refining them, but in addition for separating them from their ores, for the manufacture of chemical compounds before unknown, and for the cheap production of numerous substances of use in the various arts on a large scale. Vast quantities of copper are refined, and silver and gold often obtained from residues in sufficient amount to pay well for the process.

At Niagara also are works for the production of the metal aluminum from its ores. Similar works exist at other places here and abroad where power is cheap. This metal, which competes in price with brass, bulk for bulk, was only obtainable before its electric reduction at $25 to $30 per pound. The metal sodium is also extracted from soda. A large plant at Niagara also uses the electric current for the manufacture of chlorine for bleach, and caustic soda, both from common salt. Chlorate of potassium is also made at Niagara by electrolysis. The field of electro-chemistry is, indeed, full of great future 295
possibilities. Large furnaces heated by electricity, a single one of which will consume more than a thousand horse-power, exist at Niagara. In these furnaces is manufactured from coke and sand, by the Acheson process, an abrasive material called carborundum, which is almost as hard as diamond, but quite low in cost. It is made into slabs and into wheels for grinding hard substances. The electric furnace furnishes also the means for producing artificial plumbago, or graphite, almost perfectly pure, the raw material being coke powder.

A large amount of power from Niagara is also consumed for the production in special electric arc furnaces of carbide of calcium from coke and lime. This is the source of acetylene gas, the new illuminant, which is generated when water is brought into contact with the carbide. The high temperature of the electric furnace thus renders possible chemical actions which under ordinary furnace heat would not take place. Henri Moissan, a French scientist, well known for his brilliant researches in electric furnace work, has even shown that real diamonds can be made under special conditions in the electric furnace. He has, in fact, probably practised in a small way what has occurred on a grand scale in nature, resulting in diamond fields such as those at Kimberley. One problem less is thus left to be solved. The electro-chemical and kindred arts are practised not alone at Niagara, but at many other places where power is cheap. Extensive plants have grown up, mostly within the five years before the close of the century. All of the great developments in this field have come about within the last decade.

The use of electricity for heating is not confined to electric furnaces, in which the exceedingly high temperature obtainable is the factor giving rise to success. While it is not likely that electricity 296
will soon be used for general heating, special instances, such as the warming of electric cars in winter by electric heaters, the operation of cooking appliances by electric current, the heating of sad-irons and the like, give evidence of the possibilities should there ever be found means for the generation of electric energy from fuel with such high efficiency as eighty per cent. or more. Present methods give, under most favorable conditions, barely ten per cent., ninety per cent. of the energy value of the fuel being unavoidably wasted.

Another application of the heating power of electric currents is found in the Thomson electric welding process, the development of which has practically taken place in the past ten years. In this process an exceedingly large current, at very low electric pressure, traverses a joint between two pieces of metal to be united. It heats the joint to fusion or softening; the pieces are pushed together and welded. Here the heat is generated in the solid metal, for at no time during the operation are the pieces separated. The current is usually obtained from a welding transformer, an example of an extreme type of step-down transformer. Current at several hundred volts passed into the primary winding is exchanged for an enormous current at only two or three volts in the welding circuit in which the work is done. The present uses of this electric welding process are numerous and varied. Pieces of most of the metals and alloys, before regarded as unweldable, are capable of being joined not only to pieces of the same metal, but also to different metals. Electric welding is applied on the large scale, making joints in wires or rods, for welding wagon and carriage wheel tires, for making barrel-hoops and bands for pails, for axles of vehicles, and for carriage framing. It has given rise to special manufactures, such as electrically welded steel pipe or tube, wire fencing, etc. It is used for welding together the joints of 297 steel car-rails, for welding teeth in saws, for making many parts of bicycles, and in tool making. An instance of its peculiar adaptability to unusual conditions is the welding of the iron bands embedded within the body of a rubber vehicle tire for holding the tire in place. For this purpose the electric weld has been found almost essential.

Another branch of electric development concerns the storage of electricity. The storage battery is based upon principles discovered by Gaston Planté, and applied, since 1881, by Brush, by Faure, and others. Some of the larger lighting stations employ as reservoirs of electric energy large batteries charged by surplus dynamo current. This is afterwards drawn upon when the consumer’s load is heavy, as during the evening. The storage battery is, however, a heavy, cumbrous apparatus, of limited life, easily destroyed unless guarded with skill. If a form not possessing these faults be ever found, the field of possible application is almost limitless.

The above by no means complete account of the progress in electric applications during the century just closed should properly be supplemented by an account of the accompanying great advances regarded from the purely scientific aspect. It is, however, only possible to make a brief reference thereto within the limits of this article. The scientific study of electricity and the application of mathematical methods in its treatment has kept busy a host of workers and drawn upon the resources of the ablest minds the age has produced. Gauss, Weber, Ampère, Faraday, Maxwell, Helmholtz, are no longer with us. Of the early founders of the science we have yet such men as Lord Kelvin, formerly Sir William Thomson, Mascart, and others, still zealous in scientific work. Following them are a large number, notable for valuable contributions to the progress of electrical science, in discoveries, in research, and in mathematical treatment of the various problems presented. Modern 298 magnetism took form in the hands of Rowland, Hopkinson, Ewing, and many other able workers. Maxwell’s electro-magnetic theory of light is confirmed by the brilliant researches of the late Dr. Hertz, too early lost to science. Hertz proved that all luminous phenomena are in essence electrical. The wireless telegraphy of to-day is a direct outcome of Hertz’s experiments on electric waves. It is but little more than ten years since Hertz announced his results to the world. His work, supplemented by that of Branly, Lodge, Marconi, and others, made wireless telegraphy a possibility.

The wonderful X-ray, and the rich scientific harvest which has followed the discovery by Röntgen of invisible radiation from a vacuum tube, was preceded by much investigation of the effects of electric discharges in vacuum tubes, and Hittorf, followed by Crookes, had given special study to these effects in very high or nearly perfect vacua. Crookes, though especially enriching science by his work, missed the peculiar X-ray, which, nevertheless, must have been emitted from many of his vacuum tubes, not only in his hands, but in those of subsequent students. It was as late as 1896 that Röntgen announced his discovery. Since that time several other sources of invisible radiation have been discovered, more or less similar in effect to the radiations from a vacuum tube, but emitted, singular as the fact is, from rare substances extracted from certain minerals. Leaving out of consideration the great value of the X-ray to physicians and surgeons, its effect in stimulating scientific inquiry has almost been incalculable. The renewed study of effects of electric discharge in vacuum tubes has already, in the work of such investigators as Lenard, J. J. Thomson, and others, apparently carried the subdivision of matter far beyond the time-honored chemical atom, and has gone far towards showing the essential unity of all the chemical elements. It is as unlikely that the mystery of the material universe will ever be completely solved as it is that we can gain an adequate conception of infinite space or time. But we can at least extend the range of our mental vision of the processes of nature as we do our real vision into space depths by the telescope and spectroscope. There can now be no question that electric conditions and actions are more fundamental than many hitherto so regarded. 299

The nineteenth century closed with many important problems in electrical science unsolved. What great or far-reaching discoveries are yet in store, who can tell? What valuable practical developments are to come, who can predict? The electrical progress has been great—very great—but after all only a part of that grander advance in so many other fields. The hands of man are strengthened by the control of mighty forces. His electric lines traverse the mountain passes as well as the plains. His electric railway scales the Jungfrau. But he still spends his best effort, and has always done so, in the construction and equipment of his engines of destruction, and now exhausts the mines of the world of valuable metals, for ships of war, whose ultimate goal is the bottom of the sea. In this also electricity is made to play an increasingly important part. It trains the guns, loads them, fires them. It works the signals and the search-lights. It ventilates the ship, blows the fires, and lights the dark spaces. Perhaps all this is necessary now, and, if so, well. But if a fraction of the vast expenditure entailed were turned to the encouragement of advance in the arts and employments of peace in the twentieth century, can it be doubted that, at the close, the nineteenth century might come to be regarded, in spite of its achievements, as a rather wasteful, semi-barbarous transition period?

Elihu Thomson.

303

PHYSICS

On January 7, 1610, Galileo, turning his telescope towards Jupiter, was the first to see the beautiful system of that planet in which the universe is epitomized. He had already studied the variegated surface of the moon, and he had seen the spots upon the sun. A little later, in spite of the feeble power of his instrument, he had discovered that the sun rotates upon an axis, and something of the wonderful nature of the planet Saturn had been revealed to him. The overwhelming evidence thus afforded of the truth of the hypothesis of Copernicus made him its chief exponent. The time had come for man to know, as he had never known or even dreamed before, his true relation to the universe of which he was so insignificant a part. In a single year nearly all of these capital discoveries were made. It was truly an era of intellectual expansion; never before and never since has man's intellectual horizon enlarged with such enormous rapidity. One needs little imagination to share with this ardent philosopher the enthusiasm of the moment when, because some, fearing the evidence of their senses, refused to look through the slender tube, he wrote to Kepler: "Oh, my dear Kepler, how I wish we could have one hearty laugh together!... Why are you not here? What shouts of laughter we should have at this glorious folly!"

Galileo died in 1642, and in the same year Newton was born. When twenty-four years old he "began to think of gravity extending to the orb of the moon," and before the end of the century he had 304 discovered and established the great law of universal gravitation. Thus, at the end of the seventeenth century, the foundations of modern physics were in place. During the eighteenth century they were much built upon, but it was the nineteenth that witnessed not only the greatest advance in detail, but the most important generalizations made since the time of Galileo and Newton.

In endeavoring to present to the intelligent but perhaps unscientific reader a brief review of the accomplishments of that "wonderful century" in the domain of physics, one must not attempt more than an outline of greater events, and it will be convenient to arrange them under the several principal subdivisions of the science, according to the usually accepted classification.

HEAT

Although more than one philosopher of the seventeenth and eighteenth centuries suggested the identity of heat and molecular motion, the impression made was not lasting, and up to very near the beginning of the nineteenth century the *caloric* theory was accepted almost without dispute. This theory implied that heat was a subtle fluid, definite quantities of which were added to or subtracted from material substances when they became hot or cold. As carefully conducted experiments seemed to show that a body weighed no more or no less when hot than when cold, it was necessary to attribute to this fluid called caloric the mysterious property of imponderability, that is, unlike all forms of ordinary matter, it possessed no weight. To avoid calling it matter, it was by many classed with light, electricity, and magnetism, as one of the *imponderable agents*. Various other properties were attributed to caloric, necessary to the reasonable explanation of a steadily increasing array of experimental facts. 305 It was declared to be elastic, its particles being mutually self-repellent. It was thought to attract ordinary matter, and an ingenious theory of caloric was constructed, modelled upon Newton's famous but erroneous corpuscular theory of light. During the latter part of the eighteenth century Joseph Black, professor in the Universities of Glasgow and Edinburgh, developed his theory of *latent heat*, which, although founded upon a false notion of the nature of heat, was a most important contribution to science. The downfall of the caloric theory must be largely credited to the work of a famous American who published the results of his experiments just at the close of the eighteenth century.

Benjamin Thompson, generally known as Count Rumford, was born in the town of Woburn, Massachusetts, in 1753. His inclination towards physical experimentation was strong in his early youth, and he received much instruction and inspiration from the lectures of Professor John Winthrop, of Harvard College, some of which he was enabled to attend under trying conditions. Having received special official consideration by appointment to office under one of the colonial governors, he was accused at the breaking out of the Revolutionary War of a leaning towards Toryism, and was thus prevented from making his career among his own people. At the age of twenty-two years he fled to England, returning to America only for a brief period in command of a British regiment. In England he soon became eminent as an experimental philosopher, and in 1778 became a Fellow of the Royal Society. He afterwards entered the service of the Elector of Bavaria, by whom he was made a Count of the Holy Roman Empire. In 1799 he returned to London and founded the "Royal Institution," which was destined during the next hundred years to surpass all other foundations in the richness and importance of its contributions to physical science. It was while at Munich that Rumford made his 306 famous experiments on the nature of heat, to which he had been led by observing the great amount of heat generated in the boring of cannon. Finding that he was able to make a considerable quantity of water actually boil by the heat generated by a blunt boring tool, he concluded that the supply of heat from such a source was practically inexhaustible and that it could be generated continuously if only the motion of the tool under friction was kept up. He declared that anything which could thus be produced without limitation by an insulated body or system of bodies could not possibly be a material substance, and that under the circumstances of the experiment, the only thing that was or could be thus continuously communicated was *motion*.

Count Rumford's conclusions were not for a long time accepted. Davy, the brilliant professor and eloquent lecturer at the newly established Royal Institution, espoused the mechanical theory of heat and made the striking experiment of melting two pieces of ice by rubbing them together remote from any source of heat. His contemporary, Thomas Young, who overturned Newton's corpuscular theory of light and showed that it was a wave phenomenon, also advocated Rumford's notion of the nature of heat, but even among physicists of high rank it had made little headway as late as the middle of the nineteenth century. In the eighth edition of the Encyclopædia Britannica, published in 1856, the immediate predecessor of the current issue, heat is defined as "a material agent of a peculiar nature, highly attenuated." And this, in spite of the fact that previous to that date the mechanical theory had been completely proved by the labors of Mayer, Joule, Helmholtz, and William Thomson (Lord Kelvin). By these men a solid foundation for the theory had been found in a great physical law of such importance that it is justly considered to be the most far-reaching generalization in natural philosophy 307 since the time of Newton. Some account of this law and its discovery will be given later in this paper.

Among the most important of the century's contributions to our knowledge of heat must be included the work of Fourier, as embodied in his *Theorie Analytique de la Chaleur*, published in 1822. Joseph Fourier was born in 1768, and died in 1830. He belonged to that splendid group of philosophers of which the French nation may always be proud, whose work constitutes a large part of the lustre of intellectual France during her most brilliant period, the later years of the eighteenth and the earlier years of the nineteenth century. His contemporaries included such men as Laplace, Arago, Lagrange, Fresnel, and Carnot. Fourier wrote especially of the movement of heat in solids, and as his thesis depended in no way on the nature of heat it will always be regarded as a classic. His assumption that conductivity was independent of temperature was shortly proved to be erroneous, but his general argument and conclusions were not greatly affected by this discovery. His work is one of the most beautiful examples yet produced of the application of mathematics to physical research, and mathematical and physical science were equally enriched by it. In its broader aspects his law of conduction includes the transfer of electricity in good conductors, and is the real basis of Ohm's law.

One of the most skillful and successful experimenters in heat was also a Frenchman, Henri Victor Regnault (1810–78). He greatly improved the construction and use of the thermometer, and was the first to discover that the indications of an air thermometer and one of mercury did not exactly agree, because they did not expand in the same degree for equal increases of temperature. His most important work was on the expansion of gases, vapor pressure, specific heat of water, etc., and for careful, 308 patient measuring he had a positive genius. Until he proved the contrary it had been assumed that all gases had the same coefficient of expansion, and Boyle's law that the volume of a gas was inversely proportional to its pressure had not been questioned. His tables of the elastic force of steam have been of immense practical value, but his studies of the expansion of gases are of greater interest because they have pointed the way to one of the most important accomplishments of the century, the liquefaction of all known gases.

During the earlier years of this century it was the custom to consider vapors and gases as quite distinct forms of matter. Vapors always came, by evaporation, from liquids, and could always be "condensed" or reduced to the liquid form without difficulty, but it was not thought possible to liquefy the so-called "permanent" gases. The first man to attack the problem systematically was Michael Faraday, who, before the end of the first third of the century, had liquefied several gases, mostly by producing them by chemical reactions under pressure. Several of the more easily reducible gases or vapors, such as ammonia, sulphurous acid, and probably chlorine, had been previously liquefied by cold, but a quarter of a century elapsed after Faraday's researches before the true relation of the liquid and gaseous states of matter was understood, and it was found that both increase of pressure and lowering of temperature were, in general, essential to the liquefaction of a gas. It was Thomas Andrews, of Belfast, who first showed, in a paper published in 1863, that there was a continuity in the liquid and gaseous states of matter, that for each substance there was a critical temperature at which it became a homogeneous fluid, neither a liquid nor a gas: that above this temperature great pressure would not liquefy, while below it the substance might exist as partly liquid and partly gas. He pointed out the fact that for the so-called permanent gases this critical temperature must be exceedingly low, 309
and if such temperature could be reached liquefaction would follow.

Subsequent progress in the liquefaction of gases came about by following this suggestion. Very low temperatures were produced by subjecting the gas to great reduction in volume by pressure, removing the heat of compression by conduction and radiation, and then by sudden expansion its temperature was greatly lowered. As early as 1877 two Frenchmen, Pictet and Cailletet, had succeeded in liquefying oxygen, hydrogen, nitrogen, and air. During the past twenty years great improvements have been made in the methods of accomplishing these transformations, so that to-day it is easy to produce considerable quantities of all of the principal gases in a liquid form, and by carrying the reduction in temperature still further portions of the liquid may be changed to the solid state. The most important work along this line has been done by Wroblewski and Olszewski, of the University of Cracow, and Professor Dewar, of the Royal Institution in London. Temperatures as low as about two hundred and fifty degrees C. below the freezing-point of water have been produced, the "absolute zero" being only two hundred and seventy-three degrees C. below that point. These experiments promise to throw much light on the nature of matter, and they are especially interesting as revealing its extraordinary properties at extremely low temperatures. Among the most curious and suggestive is the fact that the electrical resistance of pure metals diminishes at a rate which indicates that at the absolute zero it would vanish, and these metals would become perfect conductors of electricity.

The dynamics of heat, or "thermo-dynamics," was an important field of research in the early part
of the century, on account of its practical application to the improvement of the steam-engine. The 310
science was created by Carnot, who, in spite of the fact that his views regarding the nature of heat were erroneous, discovered some of the most interesting relations among the quantities involved, and discussed their applications to the heat engines with great skill. Subsequent contributors to the theory and practice of thermo-dynamics were Clausius, Rankine, Lord Kelvin, and Professor Tait.

The mechanical theory of heat naturally led up to what has already been referred to as the most important generalization in physical science since the time of Newton, the doctrine of

THE CONSERVATION OF ENERGY

This principle puts physics in its relation to energy where chemistry has long been in its relation to matter. If matter were not conservative, if it could be created or destroyed at will, chemistry would be an impossible science. Physics is put upon a solid foundation by the assumption of a like conservatism in energy; it can neither be created nor destroyed, although it may appear in many different forms which are, in general, mutually interconvertible.

Many men have contributed to the establishment of this great principle, but it was actually discovered and proved by the labors of three or four. Although it was practically all done before the middle of the nineteenth century, its general popular recognition did not come until a quarter of a century later. The doctrine was first distinctly formulated by Robert Mayer, a German physician, who published in 1842 a suggestive paper on "The Forces of Inorganic Nature," which, however, attracted little or no attention. Mayer had not approached the problem from an experimental stand-point, but at about the same time it was attacked most successfully from this side by a young Englishman, James 311
Prescott Joule, son of a wealthy brewer of Manchester, England. Joule made the first really accurate determination of the mechanical equivalent of a given quantity of heat, a physical constant which Rumford had tried to measure, reaching only a rough approximation. Substantially Joule's result was that the heat energy necessary to raise the temperature of any given mass of water one degree Fahr. is the equivalent of the mechanical energy required to lift that mass through a height of seven hundred and seventy-two feet against the force of the earth's attraction; and, conversely, if a mass of water be allowed to fall through a distance of seven hundred and seventy-two feet under the action of gravity, and at the end of its motion be instantly arrested, the heat generated will suffice to raise its temperature one degree Fahr. Of such vast importance is this numerical coefficient that it has been called the golden number of the nineteenth century. Since Joule's time it has been redetermined by several physicists, notably by Professor Rowland, of Baltimore, the general conclusion being that Joule's number was somewhat, but not greatly, too small.

The first clear and full exposition of the doctrine of the conservation of energy was given by Joule in a popular lecture in Manchester in 1847, but it attracted little attention until a few months later, when the author presented his theory at a meeting of the British Association for the Advancement of Science. Even among scientific men it would have passed without comment or consideration had it not been for the presence of another young Englishman, then as little known as Joule himself, who began a series of remarks, appreciative and critical, which resulted in making Joule's paper the sensation of the meeting. This was William Thomson, who had been, only a year before, at the age of twenty-two years, appointed professor of natural philosophy at the University of Glasgow, now known as Lord 312
Kelvin, the most versatile, brilliant, and profound student of physical science which the century has produced. From that day to the death of Joule (1889) these two men were closely associated in the demonstration and exploitation of a great principle of which they were at first almost the sole exponents among English-speaking people.

By an interesting coincidence, in the same year in which Joule announced the result of his experiments, the Physical Society of Berlin listened to a paper almost identical with Joule's in character and conclusions, but prepared quite independently, by a young German physician, Herman von Helmholtz, destined to rank at the time of his death, in 1893, as one of the very first mathematicians of the age, doubtless the first physiologist of his time, and as a physicist with whom not more than one other of the nineteenth century may be compared. Helmholtz's paper was rejected by the editor of the leading scientific journal of Germany, but his work was so important that he must always share with Joule and Kelvin in the glory of this epoch-making generalization.

Even a brief sketch of the history of the doctrine of the conservation of energy would be incomplete if mention were not made of the work of Tyndall. Although by original research he contributed in no small degree to the demonstration of the theory, it is mainly through his wonderful skill in popular presentation of the principles of physical science that he becomes related to the great movement of the middle of the century. His masterful exposition of the new theory in a course of lectures at the Royal Institution, given in 1862 and published in 1863 under the title *Heat as a Mode of Motion*, was the means of making the intelligent public acquainted with its beauty and profound significance, and the history of science affords no more admirable example of the possibilities and 313
wisdom of popular scientific writing than this book. As for the principle of the conservation of energy itself it is not too much to say that during the last half of the century it has been the guiding and

controlling spirit of all scientific discovery or of invention through the application of scientific principles.

LIGHT

The revival and final establishment of the undulatory or wave theory of light is one of the glories of the nineteenth century, and the credit for it is due to Thomas Young, an Englishman, and Fresnel, a Frenchman. Newton had conceived, espoused, and, owing to the great authority of his name, almost fixed upon the learned world the corpuscular or emission theory, which assumes that all luminous bodies emit streams of minute corpuscles, which are reflected, refracted, and produce vision. Many ordinary optical phenomena were explained by this hypothesis only with great difficulty, and some were quite unexplainable. The transmission of a disturbance or vibratory motion by means of waves, as in the case of sound, was a well-recognized principle, and Young and Fresnel applied it most successfully to the phenomena of light. Wave motion, in a general way, is only possible in a sensibly continuous medium, such as water, air, etc., and the theory that light was a vibratory disturbance transmitted by means of waves necessitated the assumption of the existence of such a medium throughout all space in which light travelled. What is known as the ethereal medium, at first a purely imaginary substance, but whose real existence is practically established, satisfies this demand, and the hypothesis that light is transmitted by waves in such a medium, originating in a vibratory disturbance at the source, has been of inestimable value to physical science.

The work of Thomas Young was done in the very first years of the nineteenth century. He was for 314
two years professor of Natural Philosophy in the Royal Institution just founded by Count Rumford, and he was the first to fill that chair. In 1801, in a paper presented to the Royal Society, he argued in favor of the undulatory theory, showing how the interference of waves would explain the color of thin plates. His papers were not, for several years, received favorably, and they were severely criticised by Lord Brougham. Augustus Fresnel followed Young, but quite independently, about ten years later, and by him the undulatory theory received elaborate experimental and mathematical treatment.

In the mean time another Frenchman had made a capital discovery in optics, which seemed at first to be quite incompatible with the wave theory. This was the discovery of what is known as *polarization of light* by Malus, a French engineer, who hit upon it while investigating double refraction of crystals, for a study of which the French Institute had offered a prize in 1808. Malus found that when light fell upon a surface of glass at a certain angle a portion of the reflected light appeared to have acquired entirely new properties in regard to further reflection, and the same was true of that part of the beam which was transmitted through the glass. The light thus affected was incapable of further reflection under certain conditions, and as the beam seemed to behave differently according to how it was presented to the reflecting surface, the term polarization was applied to the phenomenon. It was found that the two rays into which a single beam of light was split by a doubly refracting crystal (a phenomenon which had long been known) were affected in this way, and that light was polarized by
refraction as well as by reflection. Malus was a believer in the corpuscular theory of light, but it was 315
shortly proved, first by Thomas Young, that the phenomenon of polarization was not only not opposed to the wave theory, but that that theory furnished a rational explanation of it. This explanation, in brief, assumes that ordinary light is a wave produced by a vibratory motion confined to no particular plane, the direction of vibration being at right angles to the direction of the wave, and in any, or, in rapid succession, in *all* azimuths. When light is polarized the vibratory motion in the ether is restricted to one particular form, a line if plane polarized, a circle or an ellipse if circularly or elliptically polarized. This simple hypothesis has been found quite adequate, and through its application to the various phenomena of polarization, together with the application of Young's theory of the interference of waves to the production of color, the undulatory theory of light was firmly established before the middle of the century. There were many noted philosophers, however, who stood out long against it, notably Brewster, the most famous English student of optics of the early part of the century, who declared that his "chief objection to the undulatory theory was that he could not think the Creator

guilty of so clumsy a contrivance as the filling of space with ether in order to produce light." In studying the nature of light it became very important to know how fast a light wave travelled. A tolerably good measure of the velocity of light had been made long before by means of the eclipses of Jupiter's moons and by observations upon the positions of the stars as influenced by the motion of the earth in its orbit. It was found to be approximately one hundred and eighty thousand miles per second, a speed so great that it seemed impossible that it should ever be measured by using only terrestrial distances.

This extremely difficult problem has been solved, however, in a most satisfactory manner by nineteenth-century physicists. Everybody knows that in a uniform motion velocity is equal to space or 316 distance divided by time. If, then, the time occupied in passing through a given distance can be measured, the velocity is at once known. As the velocity of light is very large, unless the distance is enormously great, the time will be extremely small, and if moderate distances are to be used the problem is to measure very small intervals of time very accurately. Light will travel one mile in about the one hundred and eighty-sixth thousandth part of a second, and if by using a mile as the distance the velocity of light is to be determined within one per cent., it is necessary to be able to detect differences of time as small as about one twenty-millionth of a second. This has been made possible by the use of two distinct methods. Foucault, on the suggestion of Arago, used a rapidly revolving mirror, a method introduced by Wheatstone, the English electrician, who used it in finding the duration of an electric spark. The essential principle is that a mirror may be made to revolve so rapidly that it will change its position by a measurable angle, while light which has been reflected from it passes to a somewhat distant fixed mirror and returns to the moving reflector. In the other method a toothed wheel is revolved so rapidly that a beam of light passing between two consecutive teeth to a distant fixed mirror is cut off on its return to the wheel by the tooth, which has moved forward while the light has made its journey. This method was first used by Fizeau. In either method, if the speed of rotation is known, the time is readily found. In point of time, Fizeau was the first to attack the problem, which he did about 1849. Foucault was perhaps a year later in getting results, but his method is generally considered the best. Both methods have been used by other experimenters, and very important improvements in Foucault's method were made in the United States by Michelson about 1878. Michelson's method 317 increased enormously the precision of the measurements, and it has been applied by him and by Newcomb, not only for the better determination of the velocity of light in air, but for the solution of many other related problems of first importance. Michelson's final determination of the absolute velocity of light (in the ether) is everywhere accepted as authoritative.

Another discovery in optics entirely accomplished during the nineteenth century and of the very first importance is generally known as "Spectrum Analysis." This discovery has not yet ceased to excite admiration and even amazement, and especially among those who best understand it. By its use hitherto unknown substances have become known; to the physicist it is an instrument of research of the greatest power, and perhaps more than anything else it promises to throw light on the ultimate nature of matter; to the astronomer it has revealed the composition, physical condition, and even the motions of the most distant heavenly bodies, all of which the philosophy of a hundred years ago would have pronounced absolutely impossible.

The beginning of spectrum analysis was in 1802, when an Englishman, Dr. Wollaston, observed dark lines interrupting the solar spectrum when produced by a good prism upon which the sunlight fell after passing through a narrow slit. About ten years later, Fraunhofer, at Munich, a skilful worker in glass and a keen observer, discovered in the spectrum of light from a lamp two yellow bands, now known as the sodium, or "D" lines. Combining the three essential elements of the modern spectroscope, the slit, the prism, and the observing telescope, he saw in the spectrum of sunlight "an almost countless number of dark lines." He was the first to use a grating for the production of the spectrum, using at first fine wire gratings and afterwards ruling fine lines upon glass, and with these he 318 made the first accurate measures of the length of light waves. He did not, however, comprehend the full import of the problem which he thus brought to the attention of physicists. About twenty years later Sir John Herschell studied the bright line spectra of different substances and found that they might be used to detect the presence of minute quantities of a substance whose spectrum was known. Wheatstone studied the spectrum of the electric arc passing between metals, and in 1874 Dr. J. W.

Draper published a very important paper on the spectra of solids with increasing temperature. Although quite in the dark as to the real nature of the phenomena with which they were dealing, these observers paved the way for the splendid work of the two Germans, Kirchoff and Bunsen, who, about 1860, found the key to this wonderful problem and made the science of spectrum analysis substantially what it is to-day. Its fundamental principles may be considered as few and comparatively simple.

Waves of light and radiant heat originate in ether disturbances produced by molecular vibration, and have impressed upon them all of the important qualities of that vibration. Molecules of different substances differ in their modes of vibration, each producing a wave peculiar to and characteristic of itself. A useful analogy may be found in the fact that when one listens to the music of an orchestra without seeing it it is easy to recognize the tones that come from each of the several instruments, the characteristic vibrations of each being impressed upon the waves in air which carry the sound to the ear. So delicate and so sure is this impression of vibration peculiarities that it is even possible to know the maker of a violin, for instance, by a characteristic *timbre* which must have its physical expression in the sound wave. The ear, more perfect than the eye, analyzes the resultant disturbance into its 319
component parts so that each element may be attributed to its proper source. Unaided, the eye cannot do this with light, but the spectroscope separates the various modes of vibration which make up the confused whole, so that varieties of molecular activity are recognizable. The speed at which a source of sound is approaching or receding from the ear can be ascertained by noting the rise or fall in pitch due to the crowding together or stretching out of the sound waves, and in the same way the motion of a luminous body is known from the increase or decrease of the refrangibility of the elements of its spectrum.

Indeed, had nineteenth-century science accomplished nothing else than the discovery of spectrum analysis, it would have marked the beginning of a new epoch. By this device man is put in communication with every considerable body in the universe, including even the invisible. The “goings on” of Sirius and Algol, of Orion and the Pleiads are reported to him across enormous stretches of millions of millions of miles of space, empty save of the ethereal medium itself, by this most wonderful “wireless telegraphy.” And it is by the vibratory motion of the invisibly small that all of this is revealed; the infinitely little has enabled us to conquer the inconceivably big.

Many important contributions to the theory and practice of spectrum analysis have been made since the time of Kirchoff and Bunsen, only two or three of which can be referred to here. Instrumental methods by which spectra are produced and examined have been greatly perfected, and this is especially true of what is known as the “diffraction grating” first used by Fraunhofer. A quarter of a century ago Rutherford, of New York, constructed a ruling engine by means of which gratings on glass and spectrum metal were ruled with a precision greatly exceeding what had before been possible. A 320
few years later Rowland, of Baltimore, made a notable advance in the construction of a screw far more perfect than any before made, producing gratings of a fineness and regularity of spacing far ahead of any others, and especially by the capital discovery of the concave grating, by means of which the most beautiful results have been obtained. Very recently Michelson, of Chicago, has invented the echelon spectroscope, which, although greatly restricted in range, exceeds all others in power of analysis of spectral lines. In his hands this instrument has been most effective in the study of the influence of a strong magnetic field upon the character of the spectrum from light produced therein, a most interesting phenomenon first observed by Zeeman and one which promises to reveal much concerning the relation of molecular activity to light and to magnetic force.

The development of spectrum analysis was necessarily accompanied by a recognition of the identity of radiant heat and light. The study of radiant heat, which was carried on during the earlier years of the century by Leslie, and later by Melloni and Tyndall, by what might be called thermal methods, has been industriously pursued during the last two decades by processes similar to those adopted for visual radiation. The most notable contribution to this work is the invention of the *bolometer*, by Langley, who, at Allegheny, and later at Washington, has made exhaustive studies of solar radiation in invisible regions of the spectrum, especially among the waves of greater length than those of red light, where he has found absorption lines and bands similar in character to those observed in the visible spectrum. He has also studied the absorption of the earth’s atmosphere, the relation of energy to visual effect, and many other interesting problems, the solution of which was made possible by the use of the bolometer.

Mention must also be made of the invention by Michelson of an interference comparator, by means of which linear measurements by optical methods can be accomplished with a degree of accuracy hitherto unheard of. With this instrument Michelson has determined the length of the international prototype metre in terms of the wave length of the light of a particular spectral line, thus furnishing for the first time a satisfactory *natural* unit of length. 321

By far the most important contribution to the theory of light made during the last half of the century is that of Maxwell, who, in 1873, announced the proposition that electro-magnetic phenomena and light phenomena have their origin in the same medium, and that they are identical in nature. This far-reaching conclusion has been generally accepted and formed the basis of much of the most important work in physical research in process of elaboration as the century closed. To some of this reference will presently be made.

ELECTRICITY AND MAGNETISM

In no other department of physical science have such remarkable developments occurred during the past century as in electricity and magnetism, for in no other department have the practical applications of scientific discovery been so numerous and so far reaching in their effect upon social conditions. In a brief review of the contributions of the nineteenth century to the evolution of the telegraph, telephone, trolley-car, electric lighting, and other means of utilizing electricity, it will be possible to consider only a very few of the fundamental discoveries upon which the enormous and rather complex superstructure of to-day rests. Happily these are few in number, and their presentation is all the more important because of the fact that in the popular mind they are not accorded that 322 significance to which they are entitled, if, indeed, they are remembered at all.

The first great step in advance of the electricity of Franklin and his contemporaries (and his predecessors for two thousand years) was taken very near the end of the eighteenth century, but it must be regarded as the beginning of nineteenth-century electricity. Two Italian philosophers, Galvani and Volta, contributed to the invention of what is known as the galvanic or voltaic battery, the output of which was not at first distinctly recognized as the electricity of the older schools. By this beautiful discovery electricity was for the first time enslaved to man, who was now able to generate and control it at times and in such quantities as he desired. Although the voltaic battery is now nearly obsolete as a source of electricity, its invention must always be regarded as one of the three epoch-making events in the history of the science during the past one hundred and twenty years. For three-quarters of a century it was practically the only source of electricity, and during this time and by its use nearly all of the most important discoveries were made. Even in the first decade of the century many brilliant results were reached. Among the most notable were the researches of Sir Humphry Davy, who, by the use of the most powerful battery then constructed, resolved the hitherto unyielding alkalies, discovering sodium and potassium, and at the same time exhibited in his lectures in the Royal Institution in London the first electric arc light, the ancestor of the millions that now turn night into day.

The cost of generating electricity by means of a voltaic battery is relatively very great, and this fact stood in the way of the early development of its applications, although their feasibility was perfectly well understood. Without any other important invention or discovery than that of the voltaic battery much would have been possible, including both electric lighting and the electric telegraph. 323
Indeed, electric telegraphy had long been a *possibility*, even before the time of Galvani and Volta, but its actual construction and use was almost necessarily postponed until a second capital discovery came to remove most of the difficulties.

This was the discovery of a relation between electricity and magnetism, the existence of which had long been suspected and earnestly sought. A Danish professor, Hans Christian Oersted, was fortunate in hitting upon an experiment which demonstrated this relation and opened up an entirely new field of investigation and invention. What Oersted found was that when a conductor, as a copper wire, carrying an electric current, was brought near a freely suspended magnet, like a compass needle, the latter would take up a definite position with reference to the current. Thus an electric current moved a magnet, acted like a magnet in producing a “magnetic field.” The subject was quickly taken up by almost every physicist in Europe and America. Arago found that iron filings would cling to a wire through which a current was passing, and he was able to magnetize steel needles by means of the current. Ampère, another French physicist, studied Oersted’s wonderful discovery both experimentally and mathematically, and in an incredibly short time so developed it as to deserve the title of creator of the science of electro-dynamics.

The first to make what is known as an electro-magnet was an Englishman named Sturgeon, who used a bar of soft iron bent in a horseshoe form (as had long been common in making permanent steel magnets), and, after varnishing the iron for insulation, a single coil of copper wire was wrapped about it, through which the current from a battery was passed. There were thus two ways of producing visible motion by means of an electric current: that of Oersted’s simple experiment, in which a 324 suspended magnetic needle was deflected by a current, and that made possible by the production, at will, of an electro-magnet. The application of both of these ideas to the construction of an electric telegraph was quickly attempted, and two different systems of telegraphy grew out of them. One, depending on Oersted’s experiment, was developed in England first and afterwards in Europe; the other, that involving the use of signals produced by an electric magnet, was developed in America, and was generally known as the American method. It has long ago superseded the first method in actual practice. Its possibility depended on perfecting the electro-magnet and especially on an understanding of the principles on which that perfecting depended. For the complete and satisfactory solution of this problem we are indebted to the most famous student of electricity America has produced during the century, Joseph Henry. In 1829, while a teacher in the academy at Albany, New York, Henry exhibited an electro-magnet of enormously greater power than any before made, involving all of the essential features of the magnet of to-day. The wire was insulated by silk wrapping, and many coils were placed upon the iron core, the intensity of magnetization being thus multiplied. Henry studied, also, the best form and arrangement of the battery under varying conditions of the conductor. An electro-magnetic telegraph had been declared impossible in 1825, by Barlow, an Englishman, who pointed out the apparently fatal fact that the resistance offered to the current was proportional to the length of the conducting wire and that the strength of the current would be thus so much reduced for even short distances as to become too feeble to be detected. Henry showed that what is known as an “intensity battery” would overcome this difficulty, discovering experimentally and independently the beautifully 325 simple law showing the relation of current to electro-motive force which Ohm had announced in 1827. He also invented the principle of the relay, by which the action of a very feeble current controls the operation of a more powerful local system. It will thus be seen that the essential features of the so-called American system of telegraphy are to be credited to Henry, who had a working line in his laboratory as early as 1832.

Morse made use of the scientific discoveries and inventions of Henry, and by his indefatigable labors and persistent faith the commercial value of the enterprise was really established. In the mean time considerable progress was made in Europe. Baron Schilling, a Russian Councillor of State, devised and exhibited a needle telegraph. The two illustrious German physicists, Gauss and Weber, established a successfully working line two or three miles long in 1833, and this system was commercially developed by Steinheil in 1837. In England, Sir Charles Wheatstone made many important contributions, although using the needle system, which was afterwards abandoned. Before the middle of the century the commercial success of the electro-magnetic telegraph was assured, and in the matter of the transmission of messages distance was practically annihilated.

Oersted, Arago, Ampère, Sturgeon, and Henry had made it possible to convert electricity into mechanical energy. Motors of various types had been invented, and the possibility of using the new source of power for running machinery, cars, boats, etc., was fully recognized. Several attempts had been made to do these things, but the great cost of producing the current by means of a battery stood in the way of success. Another epoch-making discovery was necessary, namely, a method of reversing the process and converting mechanical energy into electricity. This was supplied by the genius of 326

Michael Faraday, who had succeeded Davy in the Royal Institution at London. In 1831 Faraday discovered *induction*, the key to the modern development of electricity. He showed that while Oersted had proved that a current of electricity would generate a magnetic field and set a magnet in motion, this process was reversible. A magnet set in motion in a magnetic field by a steam-engine or any other source of power would produce, in a conductor properly arranged, a current of electricity, and thus the dynamo came into existence. In this brilliant investigation he was almost anticipated by Henry, who was working at Albany along the same lines, but under much less favorable conditions. Indeed, in several of the most important points, the American actually did anticipate the Englishman. Nearly half a century elapsed before this most important discovery was sufficiently developed to become commercially valuable, and it is impossible in this place to trace the steps by which, during the last quarter of a century, the production and utilization of electricity as existing to-day was accomplished, as a result of which the century closed, as one might say, in a blaze of light; and it is unnecessary, because most people have witnessed the spread of the fire which Faraday and Henry kindled.

Faraday's discovery of induction furnished the basis of that marvellous improvement upon the telegraph by which actual speech is transmitted over hundreds and even thousands of miles. In connection with the invention of the telephone the names of Philip Reiss, Graham Bell, Elisha Gray, and Dolbear will always be mentioned, each of whom, doubtless independently, hit upon a way of accomplishing the result with more or less success. To Bell, however, belongs the honor of having first practically solved the problem and of devising a system which, with numerous modifications and improvements, has come into extensive use in all parts of the world. No other application of electricity 327
has come into such universal use, and none has contributed more to the comfort of life.

While it is doubtless true that since Faraday's time no discovery comparable with his in real importance has been made, the past twenty-five years have not lacked in results of scientific research, some of which may, in the not distant future, eclipse even that in the value of their practical applications. Among these must be ranked Clerk Maxwell's theory of electric waves and its beautiful verification in 1888 by the young German physicist, Hertz. This brilliant student of electricity succeeded in actually producing, detecting, and controlling these waves, and out of this discovery has come the "wireless telegraphy" which has been so rapidly developed within the last few years. Many other discoveries in electricity of great scientific interest and practical promise have been recorded in the closing years of the century, but the necessary limits of this article forbid their consideration.

No account of the progress of physical science during the nineteenth century would be even approximately complete without mention of other investigations of profound significance. For instance, the study of the phenomena of sound has yielded results of great scientific and some practical value. The application of the theory of interference by Thomas Young; the publication of Helmholtz's great work, the *Tonempfindungen*, in which his theory of harmony was first fully presented; the publication of Lord Rayleigh's treatise; the invention and construction by König of acoustic apparatus, the best example yet furnished of scientific handicraft; all of these mark important advances, not only in acoustics but in general physics as well. The phonautograph of Scott and König, by which a graphic record of the vibrations of the vocal chords was made possible, was ingeniously converted by Edison 328
into a speech recording and reproducing machine, the phonograph, by which the most marvellous results are accomplished in the simplest possible manner.

The century is also to be credited with the discovery and development of the art of photography, which, although not of the first importance, has contributed much to the pleasure of life, and as an aid to scientific investigation has become quite indispensable.

The wonderfully beautiful experiments of Sir William Crookes, on the passage of an electric discharge through a high vacuum, and other phenomena connected with what has been called "radiant matter," begun about a quarter of a century ago and continued by him and others up to the present time, laid the foundation for the brilliant work of Röntgen in the discovery and study of the so-called "X"-rays, the real nature of which is not yet understood. Their further investigation by J. J. Thomson, Becquerel, and others, seems to have revealed new forms and phases of radiation, a fuller knowledge of which is likely to throw much light on obscure problems relating to the nature of matter.

Concerning the "Nature of Matter," the ablest physicists of the century have thought and written much, and doubtless our present knowledge of the subject is much more nearly the truth than that of a hundred years ago. The molecular theory of gases has met with such complete experimental verification, and is so in accord with all observed phenomena, that it must be accepted as essentially correct. As to the ultimate nature of what is called matter, as distinguished from the ethereal medium, what is known as the "vortex theory of atoms" has received the most consideration. This theory was developed by Lord Kelvin out of Helmholtz's mathematical demonstration of the indestructibility of a vortex ring when once formed in a medium possessing the properties which are generally attributed to 329
the ether.

Perhaps the most remarkable as well as the most promising fact relating to physical science at the close of the nineteenth century is the great and rapidly increasing number of well-organized and splendidly equipped laboratories in which original research is systematically planned and carried out. When one reflects that for the most part during the century just ended the advance of science was more or less of the nature of a guerrilla warfare against ignorance, it seems safe to predict for that just beginning victories more glorious than any yet won.

T. C. Mendenhall.

333

WAR

It is doubtful how far, even if as civilians we get over our natural dislike of talking of military change as "progress," there has been any considerable advance in the larger aspects of military science within the century. The genius of Bonaparte, working upon the foundations laid by Frederick the Great, established a century ago principles which are essentially applicable to the military matters of the present day; and although the scientific developments of artillery and musketry have affected the dispositions of battle-fields, the essential principles of the art of preparation for war and of strategy stand where they stood before.

Scharnhorst was the Prussian officer who began to reduce the Napoleonic military system to rules applicable to the use of German armies. Under Bonaparte the whole management of the army was too often concentrated in the hands of the man of genius, and the actual method of Napoleon had the defect that, failing the man of genius at the head of the army, it broke down. The main change made by the Germans, who followed Scharnhorst, in the course of the century has been to codify the Napoleonic system so that it was possible to more generally decentralize in practice without impairing its essence. They have also established a division of its supply department (under a Minister of War) from the "brain of the army," as Mr. Spenser Wilkinson has well called it, which manages the preparation for the strategy of war and the strategy itself. These so-called Prussian principles of 334 decentralization and "initiative" are, however, not new and not Prussian, and may be discovered in the conversations of Napoleon Bonaparte. The French in 1870 had forgotten his teaching, and the Germans had retained it. It is, nevertheless, the case that the number of men placed in the field by the military powers having increased, the intelligent initiative of corps commanders and even of generals commanding divisions has become the more essential. It is impossible that the great general staff can give orders in advance which will cover the responsibility of all the inferior generals, and brains have to be added in all ranks to obedience. The commander-in-chief in the field cannot with advantage drown himself in details, and he can only provide in his orders an outline sketch which his subordinates in various parts of the field of operations have to fill in. The "initiative of subordinates" is but the natural division of labor.

If I, a civilian student of military politics, rather than a military expert, have been called upon to write upon the military progress of the century, it must be because of a desire to bring largely into the account the changes in military organization which on the continent of Europe have made it permanently national, and which in the United States made it temporarily national during the Civil War, and would make it so again in the event of any fresh struggle on a great scale in which the North American continent might become involved.

Although the "armed nation" has replaced in France, Germany, Switzerland, Austria-Hungary, Italy, Roumania, and Bulgaria the smaller professional armies of the eighteenth century, the popular belief that the numerical strength of field armies has enormously increased is not so completely well founded as at first sight might be supposed. It is true that each nation can put into the entire field of warfare larger numbers than that nation could put into the field a century ago. But it is still not beyond 335 the bounds of possibility that in certain cases small armies may produce results as remarkable as those which attended British operations in the Peninsula in the early part of the nineteenth century, and, on the other hand, although there will, upon the whole, in future continental wars, be larger armies in the field, no one general is likely personally to handle or to place upon a field of battle a larger army than that with which Napoleon traversed Europe before he invaded Russia.

The principles of pure military science as set forth in books have not been greatly changed during the nineteenth century. The Prussian Clausewitz only explained for us the doctrines of Bonaparte; and the latest writers—such as the Frenchmen Derrécagaix and Lewal—only continue Clausewitz. The theory of the armed nation has received extension, but, after all, the Prussian system in its essentials dates from Jena, and the steps by which it has produced the admirable existing armies of France, Austria, and Roumania have been but slow.

The United States stand apart. Their resources are so fabulously great that they and they alone are able to wait for war before making war preparations. No power will attack the United States. All powers will submit to many things and yield many strong points rather than fight the United States. The only territorial neighbors of the republic are not only not in a position to enter into military rivalry with her on the American continent, but are not advancing their military establishments with the growth of their or of her population. They are of themselves not only unable to attack, but equally unable in the long run effectively to resist her.

The whole question, then, unfortunately for us Europeans, is a European question, and I need 336 make but little reference to happier lands across the greater seas.

In Europe the United Kingdom stands absolutely apart. The existence of the British Empire depends less upon our armies than on our fleets. India is garrisoned by a small but costly army, sufficient for present needs, but insufficient to meet their probable growth. The home army, kept mainly in England and Ireland (and in Ireland now only because life is cheap in Ireland and the country healthy and well fitted for the drill and discipline of troops), has been chiefly a nursery for the white army in India, and will be for that in South Africa and in India. The expeditions which the country is obliged to send from time to time across the seas have but a domestic interest, and are unimportant when viewed from a world-wide military stand-point. In the event of war the attention of the country would be concentrated upon her fleets, with a view to retain that command of the sea without which her old-fashioned army would be useless.

Belgium has an old-fashioned army of another type. A small force of conscripts is “drawn” and the men are allowed to find substitutes for money. But Belgium and the other smaller Powers, except Switzerland, Roumania, and Bulgaria, may be neglected in our survey. Switzerland has developed an excellent army of a special local type, a cheap but highly efficient militia, the most interesting point about which is that, while field artillery is supposed to be difficult of creation and only to be obtained upon a costly and regular system, Switzerland produces an excellent field artillery upon a militia footing. The garrison artillery militia of Great Britain have longer training than the field artillery of the Swiss Federation, but the results of the training are very different. Similarly, while cavalry is supposed to be in the same position as artillery in these matters, Hungary produces a good cavalry upon a militia 337 system. It is, however, to the native army in India that we have to turn if we want to see what long service cavalry in past centuries used to be, for in these days of shorter service cavalry at least has suffered a decline, and, so far from cavalry, on the whole, presenting us with a picture of military progress in the century, the cavalry of the present day is not to be compared with the cavalry of the past. Roumania and Bulgaria, although small countries, have remarkable armies of the most modern type, of great strength when considered proportionately to their populations; but these need not come under our examination, because substantially they are on the Prussian plan.

Russia differs from Germany, France, and Austria in having an immense peace army. Her peace army is indeed as large as that of the whole of the Triple Alliance, and the enormous distances of Russia and the difficulties of mobilization and concentration force her into the retention and development of a system which is now peculiar to herself. The armies of Russia resemble more closely (although on a far larger scale) the old armies of the time before the changes which followed 1866 than the French, German, and Austrian armies of to-day. Italy is decreasing her army, and has been driven by her financial straits to completely spoil a system which was never good except on paper. It is doubtful whether now in a sudden war the Italians could put into the field any thoroughly good troops, except their Alpine battalions, which are equal to those of the French. The Austrian system does not differ sufficiently from those of Germany and of France to be worthy special note, although it may be said in passing that the Austrian army is now considered by competent observers to be excellent. We may take as our type of the armies of to-day those of Germany and of France. These armies are also 338 normal as regards their cost. Great Britain having no conscription, and being in the habit of paying dearly for all services, is extravagant in her military expenditure for the results obtained. Switzerland

and Russia, with their different systems, and for different reasons, obtain their armies very cheaply; and if we wish to know the cost of the modern military system it is to Germany and to France that we should turn.

Those who would study the French or German army for themselves will find a large literature on the subject. The principles which govern the establishment of an armed nation upon the modern Prussian scale, improved after the experiences of 1866 and again after those of 1870, are explained in the work of Von der Goltz, *The Nation in Arms*. Those who would follow these principles into their detailed application, and see how the armies are divided between, and nourished and supplied from the military districts of one of the great countries, will find the facts set forth in such publications as the illustrated *Annual of the French Army*, published each year by Plon, Nourrit, et Cie., or in the official handbooks published by the Librairie Militaire Baudoin.

In the time of Bonaparte and even in the time of the Second Empire in France army corps were of varying strength, and there was no certain knowledge on the part of administrators less admirable than the first Napoleon himself of the exact numbers of men who could be placed in the field. In 1870 Louis Napoleon was wholly misinformed as to his own strength and as to that of his opponents, which were, however, accurately known to Von Moltke. In these days such confusions and difficulties are impossible. The army corps of the great military powers are of equal strength and would be equally reinforced in the extraordinarily rapid mobilization which would immediately precede and immediately follow a declaration of war. The chief changes in the century have been a greater 339
exactitude in these respects, a general increase of numbers (especially a great increase in the strength of field artillery), and in these last years a grouping of the army corps into armies, which exist in Germany, France, and Russia even in time of peace, with all their generals and staffs named ready for war. In each of the great military countries the army is guided by the counsel of a general staff. Around the chief of the staff and the Minister of War are the "generals of armies," and in France a potential generalissimo (who on the outbreak of war would often be superseded by another general in the actual command). In the case of Germany the command would now be exercised by the young Emperor. In the case of France it would be exercised by the generalissimo, with the chief of the staff as his "Berthier" or major-general. Enormously important duties in the case of armies so unwieldy as the entire forces of the first line and of the second line in Germany or France and of the first line in Russia would be exercised by the "generals of armies." These generals in time of peace are called "inspectors of armies" in France, Germany, and Austria, and they inspect groups of army corps which would be united in war to form the armies which these generals would actually command. These generals also form the council of war or principal promotion board and committee of advice for the generalissimo and chief of the staff. In Germany and in Austria-Hungary the German Emperor and the Emperor-King respectively are virtual general inspectors-in-chief of the whole army, but in France and in Russia there is less unity of command. The Minister of War in Russia, in Germany, and in France is intended to be at the head of the supplies of the army in time of war, directing the administration from the capital, and not taking his place in the field.

The Prussian system, as far as the men are concerned, was adopted after the disasters of Prussia 340
early in the century, in order to pass great numbers of men through the ranks without attracting attention by keeping up a large peace army. The system is now maintained by Germany, Austria, and France for a different reason. Such powers desire to have an enormous force for war, but, for budgetary reasons, to keep with the flag in time of peace the smallest force which is consistent with training the men sufficiently to enable them upon mobilization to be brought back to their regiments as real soldiers. It is these considerations which have induced the younger and more thoughtful of the Prussian generals to force on Germany a reduction of the period of infantry service to two years. The army in time of peace becomes a mere training-school for war, and the service is made as short as possible, given the necessity of turning out a man who for some years will continue to have the traditions of a soldier. It is a question whether something has not been sacrificed, in France, at all events, to uniformity. A longer period of training is undoubtedly necessary to make an efficient cavalry soldier than is necessary to make an efficient infantry private; and a man who has served about two and a half years only in a cavalry regiment cannot in the majority of cases be brought back into the cavalry after he has returned to civil life. Cavalry, in the modern armies, is likely to be a

diminishing force as war goes on. The armies will enter upon war with a number of infantry which can be kept up, the losses of war being supplied by reserve men as good as the men of the first line; but each army will enter upon war with a force of cavalry which will be rapidly destroyed if it is much used, and which will not be replaced in the same manner. The reserve cavalry of which the French press boasts is a paper force, and the pretended mobilization of two of its regiments a farce. The 341 French would take the field with the cavalry of the first line only, seventy-nine regiments of five hundred horses (all over six years old), or less than half the eighty-four thousand cavalry with which Napoleon marched in 1812. The same thing might possibly be said of artillery as is said of cavalry but for the fact that Switzerland tells a different story as to the possibility of rapidly training artillerymen with a considerable measure of success. The French improvised artillery of the latter part of the war of 1870 were also a creditable force, while it was discovered to be impossible to create a cavalry.

The efficiency of the reserves in France, Germany, and Austria is tested by the calling out of large portions of them every year for training, and they are found, as far as the infantry go, thoroughly competent for the work of war. The difficulties as regards cavalry are so obvious that it is becoming more and more recognized by Germany and by France that the cavalry will have to take the field as they stand in peace, and that their reserve men will have to be kept back with a view to the selection among them of those who are fit to serve as cavalry, and the relegation of the greater number to the train and other services where ability to ride and manage horses is more necessary than the smartness of a good cavalryman. France and Germany nominally look forward to the creation of two kinds of armies in time of war, one of the first line to take the field at once, and the other to guard the communications and garrison and support the fortresses, but in fact it is the intention of these powers to divide their armies into three—a field army of the first line, a field army of the second line, out of which fresh army corps will at once be created on the outbreak of war, and, thirdly, a territorial army for communications and for fortress purposes and as a last reserve. It is a portion of the French and German system that each army corps of the first line—and the same would be the case in war with the 342 second line corps—has its separate organization of ammunition train and baggage train, and draws as largely as possible its supplies from its own territorial district.

The peace strength of the great modern armies is for France and Germany about five hundred thousand men each, and the war strength between four million and five million men each. The peace strength of Russia is now over nine hundred thousand men. Of the war armies the training is not uniformly complete, but there are in Germany, France, Austria, and Roumania sufficient reserves of clothing and rifles to equip the war armies of those powers for the field.

The cost of the system of a modern army is very much less than that of the old-fashioned armies. The United Kingdom spent till lately (including loan money) about eighteen million pounds sterling upon her army, India rarely less than fourteen million pounds sterling and an average of fifteen million pounds, and the British Empire, outside the United Kingdom and India, two million pounds, or an average of thirty-five million pounds sterling in all upon land forces. The expenditure of the United Kingdom upon land forces has been permanently increased to an enormous extent by the South African war and cannot now be estimated. The expenditure of France and Germany upon land forces is greatly less; and of Russia, large as is her peace army, less again. But France and Germany in the event of war can immediately each of them place millions of armed men in the field in proper army formation and with adequate command, whereas the United Kingdom can place a doubtful three corps in the field in India with great difficulty, and, in the true sense of the word, no organized force at all at home without an incredible amount of reorganization and waste of time after the declaration of war. It is contended by the authorities responsible for the British army that two army corps could be placed in 343 the field at home, and elaborate paper arrangements exist for this purpose; but the facts are as I state them, and not as they are professed to be. It is pretended that three corps of regulars were despatched to South Africa. But the cavalry and artillery were, in fact, created by lavish expenditure a long time after the war had begun and after disasters caused by their non-existence.

Centralized as is the administrative system of France and Germany in everything except war, the necessities of modern warfare have forced upon the governments of those countries a large amount of decentralization as concerns military matters, and the less efficient military machines of the United

Kingdom and of Russia are far more centralized than are the more efficient machines of Germany and of France. The army corps districts have in the latter countries so much autonomy as to recall to the political student the federal organization of the United States rather than the government of a highly centralized modern power. As soon, however, as war breaks out, the military states of time of peace would be grouped, and the four or five groups known as "armies," also, of course, theoretically, brought together under the directing eye of the generalissimo. In the case, at all events, of Germany, unity of direction is perfectly combined with decentralization and individual initiative.

The mode in which a modern army on the anticipation of war prepares itself for the field is extraordinarily rapid in point of time as compared with the mode found necessary in the time of Napoleon Bonaparte; and it is this rapidity of mobilization and concentration which strikes the observer as the greatest change or progress of the century in connection with armies. But it is a mere consequence of railroads and telegraphs, and is only the application to military purposes of those increased facilities of locomotion which have played so great a part in the progress of the century. 344
Mobilization is, of course, the union at points fixed beforehand of the men of the reserves who bring the army up to its war footing, and the clothing and equipment of these men, and the distribution to the mobilized regiments of their full materials of war. The cavalry and horse artillery kept upon the frontier are now in a condition of permanent readiness in the principal military countries, as they would be used to cover the mobilization of the remainder of the army. The moment mobilization is accomplished concentration takes place—on the frontier in the case of the principal powers. Near the line of concentration are forts, which play a greater part in the French scheme of defence than they do in the German. The French in the days of their weakness after 1870 both constructed a line of intrenched camps and built a kind of wall of China along the most exposed portion of their eastern frontier; whereas the Germans are prepared to rely upon their field armies, supported by a few immense fortresses, such as those (on their western frontier) of Metz and Strasburg. The French keep in front of their fortresses at Nancy a strong division, which is virtually always on a war footing, and both in France and Germany the frontier corps are at a higher peace strength than those of the interior, and are meant to take the field at once so as to help the cavalry and horse artillery to protect the mobilization and concentration of the remainder, and, if possible, to disturb the mobilization and concentration of the foe. Those who would study modern armies for themselves should visit Nancy and Metz, but should not neglect the Swiss annual manœuvres.

The work of the recruit of Germany and of France, during his two years' or nearly three years' training as the case may be, is as hard as any human work; and the populations of the continental countries submit, not on the whole unwillingly, from patriotic motives, to a slavery of which the more 345
fortunate inhabitants of the United Kingdom and of the United States have no conception. The British or the Belgian paid recruit would mutiny if forced to work as works the virtually unpaid and ill-fed recruit of Russia, Germany, Austria, and France. The enormous loss to many industries which is caused by the withdrawal of the men at the age of twenty, just when they are most apt to become skilled workmen, is in the opinion of some Germans compensated for by the habit of discipline and the moral tone of stiffness and endurance which is communicated to the soldier for the rest of his life. This is perhaps more true of the German character than it is of the inhabitants of the other countries; and in France, at least, the soldier training of the entire population is a heavy drawback to industrial and to intellectual life. There are, however, as will be seen in the concluding passage of this article, other considerations to be taken into account, some of which tell the other way.

The one successful exception to the prevailing military system of the day is to be found in Switzerland, which has a very cheap army of the militia type, but one which is, nevertheless, pronounced efficient by the best judges. The mobilization of Switzerland in 1870 was more rapid than that of either Germany or France, and, great as are the strides that both France and Germany have made in rapidity of organization and as regards numbers since 1870, the Swiss also have reorganized their mobilization system since that time, and are still able, at a much less proportional cost, to place in the field at least as large a proportional force as Germany, and this force believed to be efficient, although not largely provided with cavalry.

The greatest change in the battle-fields of the future, as compared with those of a few years ago, will be found in the development and increased strength of the artillery. A modern army, when it takes 346 up a position, has miles of front almost entirely occupied with guns, and the guns have to fire over the infantry, because there is no room for such numbers of guns to be used in any other way. The attacking side (if both, indeed, in one form or another, do not attempt attack) will be chiefly occupied in obtaining positions on which to place its guns, and the repeating-rifle itself, deadly as is its fire, cannot contend at ranges over a thousand yards, unless the riflemen are heavily intrenched, with the improved shrapnel fire of modern guns. The early engagements of a war will, indeed, be engagements of cavalry massed upon the frontier on the second day of mobilization, so rapid will the opening of war in the future be. This cavalry will be accompanied by horse artillery and followed by light infantry, constantly practised in rapid marching in time of peace, or by mounted infantry. But the great battle-fields of the later weeks will be battle-fields, above all, of artillery. The numbers engaged will be so great that the heaviest of all the responsibilities of the generals will be the feeding of their troops during the battles prolonged during several days, which will probably occur, and it is doubtful how far the old generals (often grown unwieldy in time of peace) will be able to stand the daily and nightly strain of war. Jomini has said that when both sides are equally strong in numbers, in courage, and in many other elements of force, the great tragedy of Borodino is the typical battle. Lewal has pointed out that in the battles of the future such equality must be expected: “The battle will begin on the outbreak of war in the operations of the frontier regiments. The great masses as they come to the field will pour into a fight already raging. The battle will be immense and prolonged.” Promotion will probably be rapid among the generals, owing to incompetence and retirement, and certainly among other officers 347 owing to their exposure in these days of smokeless powder, when good shots can pick off officers in a manner unknown in wars which have hitherto occurred. Whether it will be possible to get armies to advance under heavy fire after the officers have been killed is doubtful, when we remember that modern armies consist of the whole population, cowards and brave men alike, and that regimental cohesion is weakened by the sudden infusion of an overwhelming proportion of reserve men at the last moment. On the other hand, in the German army the reserve men will be fewer in the first line than in the French, and the regimental system more available in the field, while on the French side the greater military aptitude of the French race may perhaps be counted upon to remedy the comparative defect. The Prussians make up for the inferior military aptitude of the German people by patriotism, discipline, and the conferring of honor and of civil employment, in after life, on all who do their duty in war. They also provide more effectively than do the French against incapacity in high place. Above all, however, we should attach importance to the wisdom of successive Kings of Prussia in treating the Prussian army as an almost sacred institution, and in constantly working in time of peace to make it and keep it a perfect instrument of war.

The weakest point, relatively speaking, in the French organization, and the strongest point, relatively speaking, in the German, is the officering of the second and third line. The one-year-volunteer system gives the Germans excellent “territorial” officers, while the French have been forced virtually to abolish it as impossible of successful application in a country so jealous of privilege as is modern France. The territorial infantry regiments of France would be excellent for the defence of fortresses, but would for field purposes be inferior to that part of the Prussian landwehr which would 348 remain over after the completion of the reserve corps. The reserve cavalry regiments of France have been created in order to provide promotion and sinecure appointments, and would not produce a cavalry fit for true cavalry service in the field. It would carry us beyond the proper limits of this article to explain how it is that the French could create a field artillery of the second line in time of war which would probably be superior to that of Germany. This forms a set-off against some other inferiority of the French.

The newest point in the development of modern armies is the recent separation in the German army of the cavalry intended for patrol duties from the cavalry intended for fighting in the field. We have had to face the same problem in South Africa, but this condition of our war was peculiar.

It has been said that the history of warfare is the history of the struggle among weapons, and that each change in tactics and even in strategy has come from scientific change affecting weapons. In the century we have seen the change from the smooth-bore to the rifle and from the ordinary to the repeating rifle. We have seen the modifications of artillery, which are beginning to give an application of the quick-firing principle to field artillery, and the use of high explosive shells, likely to affect by their explosion even those who are near the bursting shell and who are not struck by its fragments. Smokeless powder has altered the look of battles and has reduced their noise. It provides excuse for the incompetent. It would be easy, however, to exaggerate the importance of these changes as regards tactics, and still more with regard to strategy, while with tactics we are not here concerned. The great continental military nations have hitherto not allowed themselves to be much affected by the changes in the weapons, and many of the modern fads which are adopted in small armies are condemned by the 349 leaders of these great forces. The British machine guns, for example, like British mounted infantry, are generally regarded on the continent as a fancy of our own. All nations have their military fads, except, perhaps, the severely practical Germans. Russia has its dragoon organization, from which it is receding; America has her dynamite gun; the French have their submarine torpedo-boats. Our machine guns are not thought much more of by most Prussians than the steam-gun of 1844, ridiculed by Dickens in *Martin Chuzzlewit*. If great change was to have been made in the art of war by modern weapons, one would have thought that the first things to disappear would be all vestige of protective armor and the use of cavalry in the field. Yet protective armor has been recently restored to as large a proportion of many armies as used it in the wars of the beginning of the century, and the use of cavalry in the field is defended as still possible by all the highest authorities on the continent. My own opinion on such matters is that of a layman and should be worthless, but it agrees with that of several distinguished military writers. I confess that I doubt whether in future wars between good armies, such as those of France and Germany, it will be possible to employ cavalry on the field of battle, and I go so far as to think that the direct offensive, still believed in by the Prussians, will be found to have become too costly to be possible. Our South African experience is not, however, regarded by continental authorities as conclusive.

The author of *Ironclads in Action*, Mr. Wilson, who has made a very thorough study of the future of naval war, has pointed out with great force the most striking difficulties of war in the future as caused by the enormous concentration of forces in a particular tract of country. The result of that concentration must be great difficulties about supply, prolonged battles of an indecisive kind leading to exposure, absence of sleep, and to conditions which would form the severest strain for professional 350 men of war, while those who will now be subject to them will be the ordinary population, not very specially warriors, except so far as patriotism may in some cases make up as regards courage and endurance for absence of military tradition. The vast number of wounded will be exposed for longer periods than was the case in many of the earlier wars; but when we remember Leipsic, and Dresden, and the retreat from Moscow, it is again easy to see that the change is rather in the direction of generalization of conditions, which were formerly exceptional, than a change to conditions wholly without precedent.

I have all through this article written of Germany and France as the modern military countries to be taken as a standard in all comparisons. The French have imitated the Germans very closely since the war of 1870. But, although imitation is generally feeble, it must always be borne in mind that the French people have greater military aptitude than the German, and that unless beaten at the beginning of a war they are always in the highest degree formidable. The perfection of system is to be found in Germany, and the peculiarities of the German system are the combination of enlightened patriotism in all its individuality with iron discipline. The system is so strong that unless well managed it would crush out individual responsibility; but the system itself encourages this individual responsibility all down the gradations of the army to the humblest non-commissioned officer and even to the detached private. The universality of promotion by a certain high standard of merit and the absence of jobbery are more thoroughly obtained in Germany than in any other army, and Lord Wolseley's criticisms on the 1898 manœuvres of our own army, criticisms renewed in 1900, in which he told us that no one had done well in the field, and that this proved that no one could have done his duty during the past year, 351 would be impossible in Germany, and must have shocked military opinion throughout that country.

It is not unusual to assume that the enormous military establishments of the continent of Europe are an almost unmixed evil. But this may perhaps be disputed on two grounds. In some cases, such as that of Italy, the army acts as a kind of rough national university in which the varied life of districts often discordant is fused into a patriotic whole, dialects are forgotten, and a common language learned. In the case of France the new military system is a powerful engine of democracy. There is a French prince (not of the blood) serving at this moment in a squad of which the corporal is a young peasant from the same department. A few years ago I found the Duc de Luynes, who is also Duc de Chaulnes and Duc de Chevreuse, the owner of Dampierre, the personal friend of kings, serving, by his own wish, for, as the eldest son of a widow, he was exempt, as a private of dragoons, and respectfully saluting young officers, some of whom were his own tenants. The modern military system of the continent, in the case of France and Germany at least, may also, I think, be shown to have told in favor of peace. It is possible for us to occasionally demand a war with the greater freedom, because we do not as a rule know what war means. Those of us who have seen something of it with our own eyes are a very small minority. But every inhabitant of France and Germany has the reality of war brought home to him with the knowledge that those of his own kin would have to furnish their tribute of “cannon flesh” (as the French and Germans call it) at the outbreak of any war; and the influence of the whole of the women of both countries is powerfully exerted in consequence upon the side of peace.

Charles W. Dilke.

355

NAVAL SHIPS

In the conditions of naval warfare the century now closed has seen a revolution unparalleled in the rapidity of the transition and equalled in degree only by the changes which followed the general introduction of cannon and the abandonment of oars in favor of sails for the propulsion of ships of war. The latter step was consequent, ultimately, upon the discovery of the New World and of the sea-passage to India by the Cape of Good Hope. The voyage to those distant regions was too long and the remoteness from ports of refuge too great for rowing galleys, a class of vessels whose construction unfitted them for developing great size and for contending with heavy weather. The change of motive power made possible and entailed a different disposition of the fighting power, the main battery weight of ships being transferred from the bows and sterns—end-on fire—to the broadsides. The combination of these two new factors caused ships and fleets necessarily to be fought in a different manner from formerly—entailed, to use the technical word, new tactics.

The innovations thus briefly mentioned, though equally radical, were much more gradual in their progress than those witnessed by our generation. The latter have occurred not merely within the lifetime but within the memory of many who are still among us. They are embraced, easily and entirely, within the reign of Queen Victoria. It has been said, plausibly, that if a naval officer who died 356
half a century ago could revisit the earth he would find himself more at home in the ships of Elizabeth than in those of her present successor. No such sudden and sharp contrast troubled the seamen of the earlier era. It is true and interesting to note that the battle of Lepanto in 1573, although a few vessels of broadside type therein exercised a decisive influence, was fought chiefly by galleys, while in the contest with the Spanish Armada in the English Channel fifteen years later sailing ships played the leading part; but while the fact gives a valuable assistance to precision of memory by fixing an approximate date when the one type was definitely supplanted by the other, it remains that the turning-point thus indicated was reached long after cannon and sails first were used afloat, and that another century elapsed before the galley was definitively abandoned.

BIRD’S-EYE VIEW OF THE TRANSITION

A few dates will illustrate the swiftness of our recent transformations. In 1838, when the French navy reduced San Juan de Ulloa, the principal defence of Vera Cruz, and in 1840, in the British attack upon Acre, the fighting power was wholly in sailing ships such as had fought at Trafalgar thirty-five years before. Two small paddle steamers towed the French frigate into position, while the four British vessels of the same type contributed only a desultory addition to the broadsides of seven sailing ships of the line, which compelled the surrender of the fortress. The first screw ship of the line in the British navy was launched in 1852; the last sailing ship of that class went out of commission in 1860. All alike, the ships of Vera Cruz and of Acre, and their short-reigning successors, the steam frigates and ships of the line, are now as much things of the past, in sails, in engines, and in guns, as are the galleys 357
of Lepanto and the ships of the Armada. By 1870 it had been recognized everywhere that a type of vessel corresponding in essential features with the present armored battle-ships had displaced all competitors. The span of a single generation had seen the transition of the ships of Drake and Nelson to those of our own day. The career of Farragut was run in the intermediate period. His success for the most part was achieved and his renown won with vessels substantially of the older type, but with auxiliary steam-power.

It is almost needless to remark that this seemingly abrupt transition is but one incident in the startling progress made during the century in all the arts of peace as of war. Like the others, it is due to

an intellectual activity, greater probably than that of our predecessors, and directed since the peace of 1815 less upon external political interests than upon scientific investigation, and upon the application of the results to the improvement of processes of every kind. The changes in conception and in development of the instruments of naval warfare result from the increased power of dealing with refractory material which has been acquired by scientific and practical men in the laboratory and the workshop. Thus viewed, though so rapid in realization as to amount to a revolution, not only is the change seen to be the outcome of a long, though silent preparation, but it is brought also into its due relation to the general movement of the age, and found to share its special characteristics. Our ancestors of the eighteenth century had their own problems, noble and absorbing, but chiefly political in character. While new worlds were being gathered into the embrace of European civilization, the leading powers struggling among themselves for pre-eminence in the work, and while the harvest was ripening for the French Revolution, science crept forward, but slowly and silently, the pre-occupation 358
of the few, not the interest of the many.

The object of the present article is to describe the type of war vessel prevalent universally among civilized nations when the nineteenth century opened, and to trace historically the sequence of ideas and of facts which have resulted in the type whose general acceptance is seen now in the practice of the chief naval states.

SAILING SHIPS AND BROADSIDE BATTERIES

When the nineteenth century began, the ships that contended for the control of the sea were, and for two centuries had been, sailing ships with broadside batteries: the guns, that is, were distributed along both sides from the bow to the stern on one, two, three, or four decks. From the largest down, all were of this type until the very smallest class was reached. In the latter, which could scarcely be considered fighting ships, the gun power was at times concentrated into a single piece, which swept from side to side round the horizon, thus anticipating partially the modern turreted ironclad with its concentrated revolving battery.

The arrangement of guns in broadside involved anomalies and inconveniences which seem most singular when first noted. A ship in chase of another, for instance, had no guns which threw straight ahead. If it were wished to fire, in order to cripple the fleeing enemy, it was necessary to deflect from the course; and in order to bring most of the guns on one side into play the vessel had to swing round nearly at right angles to the direction of pursuit. This, of course, lost both time and ground. Broadside fire—the distribution of guns in broadside—rests, however, upon an unchangeable condition, which controls now as it did a century ago. Ships then were from three to four times as long as they were broad; the proportion now is, length from four to six times the breadth—or beam, as it is technically 359
called. Therefore, except in small vessels, where the concentration of the whole weight that can be carried in battery gave but one piece effective against a probable target, a full development of fire required the utilization of the long side of the ship rather than of its short cross-section. This is precisely analogous to the necessity that an army has of deploying into line, from any order of march, in order to develop its full musketry fire. The mechanical attainment of the last century did not permit the construction of single guns that would contain the weight of the whole battery of a big ship: but even had it, guns are not wanted bigger than will penetrate their target most effectively. When an ounce of lead will kill a man it is useless to fire a pound. The limit of penetration once reached, it is numbers, not size, that tell: and numbers could be had only by utilizing the broadside. This condition remains operative now; but as modern battle-ships present two or more kinds of target—the heavy armored and that which is light armored, or unprotected—the application of the principle in practice becomes more complicated. Batteries now are necessarily less homogeneous than they once were, because targets vary more.

DISAPPEARANCE OF BOW FIRE

The adoption of broadside batteries followed, therefore, necessarily upon increase of size and consequent length, but not upon that only. It is instructive to observe that the sailing fighting ship was derived, in part, at least, from the galley, and its resemblance in form to the latter is traceable for at least a century after the general disuse of the oar. As the galley, however, was small, it could concentrate its fire advantageously in one or two pieces, for which small number the cross-section 360 offered a sufficient line of emplacement: and as, when it could move at all, it could move in any direction, there was a further advantage in being able to fire in the direction of its motion. Hence, bow fire prevailed in galleys to the end, although the great galleasses of Lepanto and the Armada had accepted broadside batteries in great part, and whenever the galley type has recurred, as on Lake Champlain during our Revolutionary War, bow fire has predominated. The sailing ship, on the contrary, was limited as to the direction in which she could move. Taking her as the centre of a circle, she could not steer directly for much more than half the points on the circumference. Bow fire consequently was much less beneficial to her, and, further, it was found that, for reasons not necessary to particularize, her sailing, steering, and manœuvring were greatly benefited by the leverage of sails carried on the bowsprit and its booms, projecting forward of the bow, where they interfered decisively with right-ahead fire.

For all these reasons, bow fire disappeared and broadside fire prevailed; but the fundamental one to be remembered is the greater development of fire conferred by greater length. All ships—except the very small ones known as schooners, cutters, and gunboats—were broadside vessels, moved by canvas which was carried commonly on two or three masts; but into the particulars of the sails it is presumed readers will not care to enter. Being thus homogeneous in general characteristics, the ships of this era were divided commonly into three principal classes, each of which had subdivisions; but it was recognized then, as it is now in theory though too little in practice, that such multiplication of species is harmful, and our forerunners, by a process of gradual elimination, had settled down upon certain clearly defined medium types.

The smallest of the three principal classes of fighting ships were called sloops-of-war, or 361 corvettes. These had sometimes two masts, sometimes three; but the particular feature that differentiated them was that they had but one row of guns in broadside, on an uncovered deck. The offices discharged by this class of vessel were various, but in the apprehension of the writer they may be considered rightly as being above all the protectors or destroyers of commerce in transit. All ships of war, of course, contributed to this end; but the direct preying upon commerce, upon merchant ships, whose resisting power was small, was done most economically by small vessels of relatively small power. Having a given amount of tonnage to devote to commerce destroying, many small vessels are more effective than a few big ones of unnecessary force. Such being the nature of the attack, the resistance must be similar in kind. That is, a flock of merchant ships being liable to attack by many small adversaries, several small protectors would be more efficient than one or two large ones. Sloops-of-war served also as despatch vessels and lookouts of a fleet, but were less well adapted to this service than the frigate was.

THE FRIGATE AND HER GUNS

This latter celebrated and favorite class of ship stood next in order of power above the corvette, with which it might also be said to have blended; for although in the frigate class there were two, or at the most three, rates that predominated vastly in numbers over all the rest, yet the name covered many differing degrees of force. The distinguishing feature of the frigate was that it carried one complete row of guns upon a covered deck—upon a deck, that is, which had another deck over it. On this upper or spar deck there were also guns—more or fewer—but lighter in weight than those on the covered 362 deck, usually styled the main deck. The two principal classes of frigates at the beginning of this century were the thirty-two-gun and the thirty-eight-gun. That is, they carried nominally sixteen or nineteen guns on each side; but the enumeration is misleading, except as a matter of comparison, for guns of some classes were not counted. Ships generally had a few more cannon than their rate implied. The United States thirty-two-gun frigate *Essex*, for example, carried at first twenty-six long twelves on the main deck, with sixteen carronades and two chase guns on the spar deck. Above these two classes came the forty-four-gun frigate, a very powerful rate, which was favored by the United States navy and received a development of strength then unprecedented.

Being such as here described, the frigate was essentially, though not exclusively, the appendage of a fleet of line-of-battle ships. Wars are decided not by commerce destroying nor by raids, however vexatious, but by fleets and armies, by great organized masses—that is, by crushing, not by harassment. But ships of the line, to perform their function, must keep together, both when cruising and when on the field of battle, in order to put forth their strength in combination. The innumerable detached services that must be discharged for every great organized force need for a fleet to be done by vessels of inferior strength, yet so strong that they cannot be intercepted or driven off lightly by every whipper-snapper of an armed ship that comes along. Moreover, a fact not always realized, speed—speed to hasten on a mission, to overtake a foe, or to escape pursuit—depends upon size, masts that can carry sail and hold way amid heavy seas. Hence the frigate, not the lighter sloop, was indicated for the momentous duties upon which depended the intelligence and the communications of the fleet. Such leading considerations are needed to be stated and to be kept in mind, for they affected the 363 warfare of the last decade of the century quite as really as they did that of the first, and a paper would indeed be incomplete which confined itself to indicating points of difference of progress, so-called, and failed to recognize those essential and permanent conditions which time will never remove. Frigates and sloops have disappeared in name and form, in motive power and in armament. Their essential functions remain, and will remain while war lasts.

DUTIES OF THE FRIGATE

The truth of this statement will be evident from a brief mention of the duties frigates actually used to perform. While attending the fleet, not merely a part of it, the frigates were thrown out far in advance and on each side, as cavalry on land scours the country towards or through which the army advances. The distance to which they would be thus detached would sometimes amount to one hundred or two hundred miles, and the absence to days, rejoining being assured by the assignment of a rendezvous, or by an adequate knowledge of the admiral's intended movements. It will be recognized that when thus alone frigates might meet equal or superior forces, to resist or to escape from which both strength and speed were needed. An extreme and particular case of such service was the watching of an enemy's port by one or more frigates, when they had to keep close to the entrance, although a fleet might be within. Again, frigates were placed in certain central positions, rendezvous known only to the superior officers, where they cruised steadily, having information as to the whereabouts of the fleet, or instructions for expected vessels. They were there centres of intelligence, round which the movements of the whole body revolved.

When the fleet was actually in touch with a hostile fleet, in pursuit, or when expecting battle, the 364 frigates were placed between their own force and the enemy; nearer, however, to the latter, as the essential point was to keep knowledge of his whereabouts and probable intentions. Such a position was at times extremely exposed. The frigates had to avoid equally capture and being driven and shaken off; they must keep close, yet not be caught. When engagement ensued they passed through to the off side of their own fleet, where they were dispersed at intervals abreast the main line, like the file closers of a military line ashore. Here they fulfilled one special purpose, besides others. As the fleet fought with broadsides only, its ships were ranged one ahead of the other. Consequently signals made on the masts of the admiral could not be seen always by those ahead or astern of him; but the frigates in the other line made the same signals, "repeated," as it was said, where they could be read more certainly. But frigates did also more hazardous work. They went to crippled ships of the line and towed them into other positions, into or out of fire, and at times the admiral summoned a frigate alongside to carry a message to some part of the battle. "I noticed," says Marryatt, in one of his novels, "the look of pride on the faces of our officers when it appeared that the loss on board our frigate was greater than that of some of the ships in the line."

For such offices it is evident there were wanted a strength and a weight which the corvette did not have. A corvette would make poor work of towing a heavy ship, and could not carry as surely the sail needed to maintain a position. At the same time it should be observed that excess of size above the requirements stated should be exceptional. In the opinion of the writer the forty-four-gun frigate in her day possessed a fighting force and a weight of body in excess of that required by the ordinary 365 functions of her nominal class. For exceptional reasons, a few of the type were permissible in a large navy. On the other hand, it may be inferred from the long experience of the British navy, and the resultant practice, that ships of twenty-eight, twenty-four, and twenty guns, though often styled frigates, were not found satisfactory as such. In the distribution of tonnage between size and numbers, a mean must be found; and it must be added that a just mean is a very different thing from a compromise. These considerations also apply to present-day problems.

EARLY SHIPS OF THE LINE

In the fleet-ship, likewise the ship of the line, as the opening century styled the class of vessel known in the closing days as the battle-ship, our predecessors had reached a mean conclusion. The line-of-battle ship, or the ship of the line, as more usually called, differed from the frigate generically, in that it had two or more covered decks. There were one or two cases of ships with four decks, but, as a rule, three were the extreme; and ships of the line were roughly classed as two or three deckers. Under these heads two-deckers carried in their two centuries of history from fifty to eighty-four guns; three-deckers from ninety to one hundred and twenty. The increase in number of guns, resulting, as it did, from increase of size, was not the sole gain of ships of the line. The bigger ships got, the heavier were their timbers, the thicker their planking, the more impenetrable, therefore, their sides. There was a gain, in short, of defensive as well as offensive strength, analogous to the protection given by armor. "As the enemy's ships were big," wrote a renowned British admiral, "they took a great deal of drubbing."

Between the great extremes of strength indicated by fifty and one hundred and twenty guns— 366 whose existence at one and the same time was the evidence of blind historical development, rather than of intelligent relative processes—the navy of a century ago had settled upon a mean, to appreciate which the main idea and purport of the ship of the line must be grasped. The essential function of the ship "of the line" was, as the name implies, to act in combination with other ships in a line of battle. To do this was needed not only fighting power, but manœuvring ability—speed and handiness—and in order that these qualities might approach homogeneousness throughout the fleet, and so promote action in concert, the acceptance of a mean type was essential. To carry three decks of guns, a ship had to expose above water a side disproportionately high relatively to her length, her depth, and her hold upon the water. She consequently drifted rapidly when her side was turned to the wind; while, if her length was increased, and so her hold on the water, she needed more time and room to tack and to wear—that is, to turn around. Ships of this class also were generally—though not necessarily—slow.

ADVANTAGES OF THE SEVENTY-FOURS

The two-decked ship was superior in speed and in handiness, and for that reason, even when acting singly, she could put forth such power as she possessed more quickly and more certainly. But these qualities were most conspicuously valuable when ship had to act with ship. The great secret of military success, concerted action in masses, was in the hands of the two-decked ship, because in her were united to the highest point individual power and facility for combined action. And this was true not only of two-deckers in general, but of the particular species known as the seventy-four-gun ship. Ships below that rate lacked individual fighting power. Ships above it, the eighty and eighty-four, lost 367 manœuvring power because of their greater length and weight. Under the conditions of sail a fleet of seventy-fours could get out the whole power of the force more surely and more rapidly than the equivalent number of guns in ships of any other kind. Thus offensive power dictated its survival. To our own day it reads the lesson that offensive power, the *sine quâ non* of a military organization, lies not merely in the greatest strength of the single ships, but in the uniformity of their action and rapidity of their movements, as conducive to the quick putting forth of the strength of the whole body at once and in mutual support.

It may be asked naturally, why, then, were there any ships bigger or smaller than this favored type? For smaller, the answer is that short ships of lighter draught are best suited for shoal or intricate navigation. The shoals of Holland forbade heavy ships to the Dutch navy, materially reducing its fighting strength. Before France entered our Revolutionary struggle the British sent only sixty-fours to operate upon our comparatively shallow coasts and bars. As regards bigger ships, they were useful exceptionally, as were forty-four-gun frigates, and for the following reason: Every line of battle has three particularly dangerous points—the centre, because there the line, if pierced, divides into the two smaller fragments; and the flanks, or ends, because the extremities are supported less easily by the rest of the force than the centre is, one extremity being farther from the other than the centre is from either. Such local weakness could not be remedied by the use of two ships, for, if the line were properly closed, one of them could fire at the enemy only through or over the other. The sole way of giving the strength there required was by concentrating it into individual ships, either by putting on the additional battery, which gives a three-decker, or by making the seventy-four heavier, resulting in an eighty-gun 368 ship on two decks. These stronger vessels were, therefore, stationed in the centre or on the flanks of a line of battle. The particular functions, the *raison d'être*, of the three leading classes of ships of war—the sloop, the frigate, and the ship of the line—have now been stated. It remains to give an account of the chief features of the armament carried on their broadsides, as described.

BATTERIES SEVENTY-FIVE YEARS AGO

When the nineteenth century began, batteries of ships were composed of two principal classes of guns: the long gun and the short gun, or carronade. The difference between these lay in the way the weight of metal allowed for each was utilized. The long gun, as its name implies, was comparatively long and thick, and threw a small ball with a heavy charge of powder. The ball, therefore, flew swiftly, and had a long range. A carronade of the same weight was short and comparatively thin, could use only a small charge of powder, lest it burst, and threw a large ball. Its shot, therefore, moved slowly and had short range. Fired at a target—a ship's side—within range of both guns, the shot from the long gun penetrated quickly, the wood had not time to splinter badly, and a clean hole was the result. The carronade's shot, on the contrary, being both larger and slower, penetrated with difficulty, all the surrounding wood felt the strain and broke up into splinters, leaving a large jagged hole, if the shot got through. These effects were called respectively piercing and smashing, and are reproduced, in measure, upon targets representing the side of a modern ironclad. They have been likened familiarly to the effect of a pistol-ball and of a stone upon a window pane: the one goes through clean, the other crashes.

The smashing of the carronades, when fully realized, was worse than penetration, and was greatly 369 dreaded; but, on the other hand, a ship which feared them in an opponent might keep out of their range. This expedient was so effective that carronades, which did great damage until their tactics were understood, gradually fell into disfavor. Nevertheless, they remained in use till after the peace of 1815. In 1814 the battery of the U. S. S. *Essex* was chiefly carronades, and their inadequate range was a large factor in her defeat.

At the period in question guns of all sorts fired only non-explosive projectiles, solid or hollow shot. The destructive shell of the present day was used only by pieces called mortars, in vertical firing, which will be spoken of farther on. Such were not mounted on the ships of the fleet generally, nor used against shipping, except when packed in a small harbor. They did not enter into naval warfare proper. The ram and the torpedo of present warfare were unknown. On the other hand, there was practised a form of fighting which is thought now to have disappeared forever, namely, boarding and fighting hand-to-hand on the deck. Even then, however, boarding did not decide the main issue of a sea-fight, except occasionally in very small vessels. The deck of a large and fresh ship was not to be reached easily. Boarding was like the cavalry charge that routs a wavering line; the ship had been beaten at the guns before it occurred.

The real fighting was done by the long guns and carronades disposed in the broadsides. Besides rapidity and precision of fire, always invaluable, the two opponents sought advantage of position by manœuvring. They closed, or they kept apart, according to their understanding of the other's weight and kind of battery. Each tried, when possible, to lie across the bow or the stern of the enemy, for then his guns ranged from end to end of the hostile ship, while the latter's broadside could not reply. Failing 370 this extreme advantage of position, the effort was made so to place one's self that the opponent's guns could not bear—for they swept only a few degrees before and abaft the broadside—while your own could. If this also was impossible, the contestants lay side to side at a greater or less distance, and the affair became an artillery duel.

BRITISH AND FRENCH STYLES OF FIGHTING

Besides these recognized advantages of position, there was also a question upon what part of the enemy the fire should be directed. In this there were two principal schools of tactics, one of which aimed at the hull, to break down the fire of the hostile ship and destroy her fighting men, while the other sought, by pointing higher, to cut away the sails, rigging, and masts, rendering the foe helpless. The latter, in general, was the policy of the French; the former, and, it may be affirmed, the more surely successful, was the practice of the British. The two schools find their counterpart in the tactical considerations which now affect the question of rapid-fire and of heavy guns, each of which has its appropriate target, covering in the latter case the motive power, in the former the personnel.

These three leading classes of vessels, with their functions, armaments, and tactics of the single ship, as described, performed in their day and during the great maritime contests of two centuries all the duties that at any time can be required of a maritime fighting organization. By them the control of the sea in the largest sense was disputed and was determined; by them commerce was attacked, and by them it was protected. They themselves have passed away, but the military factors remain the same. The mastery of the sea and the control of its commerce—of which blockade is but a special case—are 371 now and must remain always the chief ends of maritime war. The ends continuing the same, the grand disposition of navies—their strategy—reposes upon the same principles that it ever did. Similarly, while the changes in the characteristics of ships will cause the individual vessel to be fought in manners different from its predecessors, the handling of masses of ships in battle—fleet tactics—must proceed on the same general principles as of old. The centre and the two extremities of all orders are always the points of danger; concentration upon one or two of the three, however effected, must be always the principle of action. These things, which cannot vary, form, therefore, no part of a paper which deals with changes.

THEY HAD THEIR BREAK-DOWNS THEN, TOO

There should be added for the general public the caution that the difficulties, the imperfections, and the frequent halting state of ships-of-war in commission for sea service at the present day are no new things. To the naval historian familiar with the correspondence of the past they are the inevitable attendants of all government action, wherein the most economical methods are always dominated, historically, by considerations of expediency which are political in character. The necessity of keeping the public in good-humor, and of not laying open points upon which opposition can enlarge, induces apparent economies, which sacrifice not only economy, but the best results. This is a great evil, as yet apparently inseparable from public enterprises as distinguished from private ones. If any one supposes that the ships with which Great Britain overthrew Napoleon, and with which Nelson and his contemporaries won their as yet unparalleled victories, were always or generally in good material [372] condition, he is greatly mistaken. What is different in our day, apparently, is a tendency in ships to rely for their repairs and material efficiency more upon dock-yards and workshops than upon their own resources, a disposition also to be unduly discouraged by imperfections in the motive enginery. War will correct this or war will fail. In maintaining efficiency while keeping the sea, quite as much as in fighting skill, lay the supreme excellence of officers like Nelson and Jervis. Men now ought to appreciate better than they do what difficulties of this sort seamen underwent a hundred years ago and how they refused to yield to them. "The difference between myself and the French marshals," the Duke of Wellington is reported to have said, "was as when a man starts on a journey with a new harness. What if something gives way, as in war something is sure to go wrong? Shall you stop or go back for a workman? Not so; hitch up the break with a bit of rope, or whatever comes handy, and go on. That is what I did."

The succession of cause and effect which has produced the present ship-of-war will be traced in rapid outline, in order to leave as much room as may be for the description of the essential feature of the ship herself as she now exists.

Two chief factors concur to a ship-of-war—motive power and fighting power. The displacement of sails by engines, and the progressive development of the latter, are features of the general progress of the century. The engines of a ship-of-war are differentiated from those of merchant ships chiefly by the necessity of protection. This affects their design, which must be subordinated to the requirement of being as far as possible below the water-line. The further great protection now afforded is incident rather to the use and development of armor as a part of the fighting power.

Fighting power divides into offensive and defensive. Armor now represents the latter. The fighting [373] ship in every age is the product of the race between the two, and in the nineteenth century this was unprecedented in the ground covered and in the rapidity of the pace, due to the increased power of dealing with materials, already alluded to.

CONTEST OF ARMOR AND PROJECTILE

The modern contest began with the introduction of horizontal shell fire in the third decade of the century. This term must be explained. It has been said that all ships' guns up to 1815 threw non-explosive projectiles. In practice this is true; although Nelson alludes to certain shell supplied to him for trial, which he was unwilling to use because he wished not to burn his prizes, but to take them alive. A shell is a hollow projectile filled with powder, the idea of which is that upon reaching the enemy it will burst into several pieces, each capable of killing a man, and the flame not impossibly setting woodwork on fire. It was necessary that the powder within should not explode from the combustion of the cartridge of the gun, for if it did its force, combined with the latter, might burst the gun; yet the process that should result in bursting must begin at that moment or else it would not take place at all. This difficulty was met by a short column of hard, compressed powder called the fuse, which extended from the outside to the inside of the shell. The outer end was inflamed by the charge of the gun, but from its density it burned slowly, so that the charge of the shell was not enkindled for five, ten, or more seconds. This expedient was in use over a century ago; but owing to imperfections of manufacture, no certainty was attained that the fuse might not be driven in or broken by the force of the discharge, or the shell itself be cracked and so explode prematurely. Shell, therefore, were fired [374] with very light charges; and, to obtain sufficient range—go far enough—they were used in very short, very thick guns, called bombs or mortars, to which great elevation was given. Such firing, because the shell flew high in the air, was called vertical firing, in contradistinction to the fire of the long gun or carronade, called horizontal fire because their projectiles rose little above the level.

The destructiveness of shell from ordinary guns was so obvious, especially for forts to use against wooden ships, that the difficulties were gradually overcome, and horizontal shell fire was introduced soon after the cessation of wars allowed men time for thought and change. But although the idea was accepted and the fact realized, practice changed slowly, as it tends to do in the absence of emergency. In the attack on Vera Cruz, in 1848, Farragut was present, and was greatly impressed, as with a novelty, by the effect of what he called the "shell shot," a hybrid term which aptly expresses the transition state of men's minds at the time. I remember an officer who entered the navy in 1840 telling me the respectful awe and distrust with which his superiors then regarded the new weapon, a very few of which for each gun were supplied tentatively. Ten years more, however, saw a great change, and in 1853 the attack of the Russian squadron of wooden sailing-ships upon the Turkish vessels in the Bay of Sinope gave an object-lesson that aroused the naval world to what wooden ships must expect from horizontal shell fire. In a few minutes three out of seven Turkish frigates were in flames; while of nine sailing-ships and two steamers only one of the latter escaped.

HORIZONTAL SHELL FIRE

The Crimean War followed quickly, and in 1854 the wooden steamships of the line of the allies, vessels identical in fighting characteristics with those of Trafalgar, attempted to silence masonry works 375 at Sebastopol. Though the disaster was not so great, the lesson of Sinope was reaffirmed. Louis Napoleon, a thoughtful man though scarcely a man of action, had foreseen the difficulty, and had already directed the construction of five floating batteries which were to carry armor. Before the war ended these vessels attacked the forts at Kinburn, which they compelled to surrender, losing, themselves, no men except by shells that entered the gun ports. Their armor was not pierced.

Horizontal shell fire had called for iron armor, and the two, as opposing factors, were now established in the recognition of men. The contest between the two sums up the progression and the fluctuations of military ideas which have resulted in the battle-ship of to-day, which, as the fleet-ship, remains the dominant factor in naval warfare, not only in actual fact but in present probability. From the first feeble beginnings at Kinburn to the present time, although the strife has waxed greatly in degree, it remains unchanged in principle and in kind. To exclude the shell, because, starting as one projectile, it became many after penetration, in what does it differ from excluding the rapid-fire gun, whose projectiles are many from the first, and penetrate singly?

There occurred, however, one singular development, an aberration from the normal line of advance, the chief manifestation of which, from local and temporary conditions, was in our own country. This was the transient predominance of the monitor type and idea; the iron-clad vessel, with very few very heavy guns, mounted in one or two circular revolving turrets, protected by very heavy armor. The monitor type embodied two ideas. The first was the extreme of defensive power, owing to the smallness of the target and the thickness of its armor—the hull of the vessel rising but little above 376 the water—the turret was substantially the only target. The second was an extreme compression of offensive power, the turret containing two of the heaviest guns of the day, consequently guns of the heaviest penetration, which could fire, not in one direction, nor in several, but in all directions as the turret revolved, and which were practically the sole armament of the ship. The defensive power of the monitor was absolute up to the extreme resisting endurance of its armor. Its offensive power must be considered relatively to the target to which its guns were to be opposed. If much in excess of that target's resistance, there was waste of power. Actually in our Civil War monitors were opposed to fortifications, except in one or two instances when they had to contend with the imperfect structures which the Confederates could put afloat. The target, therefore, was not in excess of their gun power. Moreover, being for coast warfare, the monitor then was necessarily of small draught and small tonnage. Her battery weight, therefore, must be small, and consequently lent itself to concentration into two guns, just as the battery weight of a schooner a century since found its best disposition in one long traversing gun.

This was the infancy period of the iron-clad ship. The race between guns and armor was barely begun, and manufacturing processes still were crude. As these improved, with astounding rapidity, the successful production of rifled cannon of ever-increasing dimensions and penetrative force imposed an increased armor protection, which at the first was obtained chiefly by an increase of thickness, *i.e.*, of weight. As guns and armor got heavier, ships had to be bigger to carry them, and, if bigger, of course longer. But the monitor idea, admirably suited to small ships, had now fast hold of men's minds—in England especially, for the United States lapsed into naval somnolence after the war—and it was 377
carried irreflectively into vessels of huge dimensions whose hulls rose much above the water. Weight for weight, the power of the gun outstripped the resistance of armor, and it soon became evident that even in a large ship perfect protection could be given only to a part of the structure. Passing over intermediate steps, the extreme and final development of the monitor idea was reached in the *Inflexible*, planned in 1876 by the British Admiralty, built in the following years, and still in service. This vessel was of eleven thousand eight hundred and eighty tons displacement. She was three hundred and twenty feet long, and of that length only the central one hundred and ten feet had protection, but that was by armor two feet thick, while armored partitions extended from each end of this side belt across the vessel, forming a box one hundred and ten feet long by seventy-four broad. Within this box were two turrets, each with sixteen inches of armor, and carrying two guns which threw a shell of a ton weight.

THE COMING OF THE MONITOR

The first monitor has been called an epoch-making ship, for she began an era. The *Inflexible* was also epoch-making, for she closed the era of the monitor pure and simple. Upon a development of three hundred and twenty feet of length she carried only four guns, of which it is not too much to say that their power was very far in excess of almost all targets that could be opposed to them. If, indeed, her possible opponents could have carried such an armor as her own all over their exposed surface, her guns would have been no heavier than needed, and the fewness must be accepted; but this was not the case. Like herself, ships of twelve thousand tons must have a penetrable target far exceeding in surface 378
the almost impregnable box she presented. The unreasonableness of the result struck men at once, though of course she had advocates. As an exception, such a ship might pass; as a type, never. It was pointed out that guns of very small power could pierce the exposed ends about the water-line, and that, as water entered by numerous holes, she would not only sink lower, but for constructional reasons, not necessary here to give, she would lose stability rapidly—become liable to overset. If under such conditions she attempted to turn round, the inclination vessels take in so doing would be enough alone to cause her to capsize. Her defenders did not deny this; but they said that the likelihood of her exposed ends being so riddled was too slight to justify alarm.

Under artillery conditions, then, this reply was plausible, though it soon ceased to be so. Even then, however, it was true that a ship with only four guns that fired very slowly, and with such an exposed surface, was liable to serious injury from a nimble antagonist firing many guns rapidly. The defensive weakness of the *Inflexible* is apparent; her offensive power, great as in the aggregate it was, was much impaired by lack of proper development, by undue compression into very few guns, the larger part of whose effect was wasted, except in the rare instances when they struck a target not often to be encountered. But this was not the only deduction from her strength through the excess of concentration. Very large guns fire very slowly, yet they are as subject to inaccuracy from the motion of the ship as is the smallest piece. Where the target is missed, it is immaterial whether the shot weighs a ton or a pound; and a gun that fires ten times to another's once has ten times the chance of hitting. It is evident, therefore, taking the *Inflexible* as she was, that a ship of the same weight and length with ten guns in broadside—twenty altogether—and with similar armor over her engines only, would have 379
at the least a fair chance against the *Inflexible*, and would be much more efficient against vessels with

average armor. Each of her ten guns firing once a minute, while the *Inflexible's* cannon required five minutes for discharge, would give over ten shots to one.

CRITICISM OF THE *INFLEXIBLE*

While the *Inflexible* was building there was born the idea whose present maturity enforces the abandonment of the pure monitor, except for vessels comparatively small and for special purposes. Machine guns, the Gatling, and the mitrailleuse were already known, and the principle was being applied to throw projectiles of a pound weight and over, which were automatically loaded and fired, requiring only to be aimed. Upon these followed the rapid-fire gun, of weight greatly exceeding theirs, the principle of which may be said to be that it is loaded by hand, but with ammunition so prepared and mechanism for loading so simple and expeditious as to permit a rate of firing heretofore unparalleled. The highest extension of this principle is reached in the five-inch gun, up to which size the cartridge and the projectile make a single package called fixed ammunition, which is placed by one motion. Together they weigh ninety-five pounds, about as much as an average man can handle in a seaway, the projectile itself weighing fifty pounds. There are, it is true, six-inch rapid-fire guns, but in them the cartridge and shell are placed separately, and it is questionable whether such increase of effect, through greater weight, as they give is not gained at a loss of due rapidity.

The *Inflexible* exemplified in an extreme form the elements of offensive and defensive strength and weakness. Four guns of enormous calibre and no other battery, except pieces so light as to be 380
useless against the thinnest armor, an impenetrable wall, covering a very limited area, and the remainder of the hull exposed, to be cut to pieces by a battery of numerous light cannon. When to the latter the rapid-fire idea was successfully applied, multiplying their efficiency three or fourfold, her position, as an example to be followed, became untenable. The monitor idea, which refused to utilize the broadside for developing fire, and aimed chiefly at minimizing the target, evidently needed qualification after a certain moderate limit of size was passed; and that limit of size was when the entire weight of battery the ship could carry sufficed only for two, or, at the most, four guns of power great enough to pierce heavy armor. Strictly, in the opinion of the writer, the monitor type should not prevail beyond the size that can bear only one turret.

In the strife of guns with armor, therefore, increase of power in guns, outstripping continually the increase of resistance in armor, called for bigger ships to bear the increased armor weight, till the latter could not possibly be placed all over the ship's body. Hence the exposed target, upon which plays the smaller battery of rapid-fire guns.

To comprehend fundamentally the subsequent development, we must recur to the rudimentary idea that a ship of war possesses two chief factors, motive force and fighting force, the latter being composed of guns mainly and of men. Corresponding to these two chief powers there were of old, and there are still, two vulnerable elements, two targets, upon one or the other of which hostile effort logically and practically must be directed. A century ago the French, aiming at sails and spars, sought the destruction of the motive force; the British directed their fire upon the guns and men. In strict 381
analogy now, the heavy guns seek the motive power, over which the heaviest armor is concentrated; the rapid-fire guns, searching the other portions of the ship, aim at the guns and men there stationed.

BATTLE-SHIPS OF THIS DAY

The logical outcome of these leading ideas is realized in the present battle-ships as follows: There are two turrets, protected by armor, the thickest that can be given them, considering the other weights the ship has to carry, and of the highest resisting quality that processes of manufacture can develop. Armor of similar character and weight protects the sides about the engines. In each turret are guns whose power corresponds to the armor which protects them. Their proper aim—not, of course, always

reached—is the heavy armored part of the enemy, chiefly the engines, the motive power. When they strike outside of this target, as often must happen, there is excess of blow, and consequent waste. The turrets are separated, fore and aft, by a distance as great as possible, to minimize the danger of a single shot or any other local incident disabling both. The fact that the ends of ships, being comparatively sharp, are less waterborne and cannot support extreme weights, chiefly limits this severance of the turrets. Between the two, and occasionally before or abaft them, is distributed the broadside rapid fire of the ship, which in its development is in contradistinction to the compressed fire of the monitor. This fire is rapid because the guns are many and because individually they can fire fast. Thus, the turret gun, twelve or thirteen inch in bore, fires once in five minutes; the five-inch rapid-fire gun thrice in one minute. The rapid-fire battery aims outside of the heaviest armor. When it strikes that, unless it chance to enter a gun port, its effect is lost; but as much the greater part of the ship is penetrable by it, 382
the chance of wasting power is less than in the case of the heavier guns. As most of a ship's company are outside the protection of the heaviest armor, the rapid-fire gun aims, as did the British in the old line-of-battle ship, at the personnel of the enemy.

The reader will comprehend that in the application of these leading ideas there is considerable variety in detail. The two turrets may be looked upon at present as the least variable factor; and in disposing armor all practice agrees that the turrets and engines receive the greatest protection. But how to distribute the total available weight of armor gives rise to varieties of practice which find their reflection in similar variety in the sizes and numbers of the rapid-fire guns, to whose penetrative force there is a corresponding thickness of armor. For example, two battle-ships now building for the United States navy have four thirteen-inch guns in turrets, and in broadside fourteen five-inch, twenty six-pounder, and six one-pounder rapid-fire guns; between the two classes they have four eight-inch guns, also mounted in smaller turrets, superimposed on the main turrets. A ship since designed will have the same thirteen-inch gun fire, but in place of the eight-inch and five-inch will have fourteen six-inch rapid-fire guns. An expert officer, discussing these, says: "In the former the weight of fire per minute is two thousand and fifty pounds on the broadside and five hundred ahead or astern, while with the latter plan it is only one thousand seven hundred and fifty on the broadside and five hundred ahead and astern. But the main objection to the second plan is that the volume of effective fire is enormously diminished by the omission of eight-inch guns. The larger area covered with their armor is fairly safe from the six-inch gun at fighting ranges, whereas the eight-inch projectile at any range, and at even a considerable angle of incidence, will penetrate it." In the judgment of the present writer the weight of 383
this argument depends upon what is behind the armor the eight-inch only will penetrate. If battery and men, it is strong, if not decisive; if motive power only, not.

HISTORY'S TEACHING AND THE FUTURE

The object of this paper has been not to present an accumulation of details, but to elucidate the principles upon which the details rest. The latter, when correct, are but the application of principles to practice. Subject to the imperfections attendant on all human work, the writer is persuaded that the greatest errors in practice—and especially the lack of homogeneousness which characterizes the present battle-ships—arise chiefly from the failure to refer back to principles. Until war has given us the abundant experience which led our predecessors to the broadside seventy-four as the rule, with occasional exceptions, we must depend upon reasoning alone for the solution of our problems; and the reasoner keeps within the limits of safety only by constant reference to fundamental facts.

The one experience of war which ships really contemporary have had was in the battle of the Yalu. Its teachings lose some value from the fact that the well-drilled Japanese used their weapons to advantage, while the Chinese were ill trained; still, some fair inferences can be made. The Japanese had a great many rapid-fire guns, with few very heavy ones, and their vessels were not battle-ships properly so-called. The Chinese, besides other vessels, had two battle-ships with heavy armor and heavy guns. Victory remained with the Japanese. In the opinion of the writer two probable conclusions can be reached: That rapid-fire guns in due proportion to the entire battery will beat down a ship 384 dependent mainly upon turret guns; that is, between two ships whose batteries are alike the issue of the contest will depend upon the one or the other gaining first a predominance of rapid fire. That done, the turret guns of the predominant ship will give the final blows to the engines and turrets of the other, whose own turret guns cannot be used with the necessary deliberation under the preponderant storm of projectiles now turned upon them. The other conclusion, even more certain than the first, is that rapid-fire guns alone, while they may determine an action, cannot make it decisive. Despite the well-established superiority of the Japanese rapid fire in that action, the Chinese battle-ships, though overborne, were not taken. Their heaviest armor being unpierced, the engines and turret guns remained effective, and they withdrew unmolested.

BATTLE-SHIPS THAT ARE TOO LARGE

The battle-ship constituted as described remains for the present the fighting ship upon which the issues of war will depend. The type is accepted by all the leading naval states, though with considerable variations in size. As regards the latter feature, the writer believes that the enormous tonnage recently given is excessive, and that the reasons which support it, too numerous and various to be enumerated at length, have the following fundamental fault: they look too much to the development of the individual ship and too little to the fact that the prime requisite of the battle-ship is facility for co-operating with other ships of its own type—facility in manœuvring together, facility in massing, facility also in subdividing when occasion demands. It may be remarked, too, that the increase of size has gone much more to increase of defensive power than of offensive—a result so contrary to the universal teachings of war as of itself to suggest pausing.

Does the present hold out any probabilities of important changes in the near future, of 385
revolutionary changes? No. For twenty-five or thirty years now we have been expecting from the ram and from the torpedo results which would displace the gun from its supremacy of centuries. Those results, however, are not yet visible. No one disputes the tremendous effects of the ram and of the torpedo when successfully used; but I believe I am correct in saying that the great preponderance of professional opinion does not attribute to them a certainty, or an approach to certainty, impairing the predominance of the gun. This is not the conclusion of mere conservation in a profession naturally conservative. The fluctuations of professional opinion have been sufficiently marked and the matter sufficiently argued to dispose of that contention. Nor is this supremacy of the gun probably a transient matter, liable to pass away with improvements greater than those of the last quarter of a century. The advantage of the gun depends upon conditions probably permanent—upon its greater range, its greater accuracy, its greater rapidity. The individual effect of each shot may be less than that of a torpedo or of a ram thrust; but, as was said in comparing very heavy guns with rapid fire, the probability of many hits prevails over the possibilities of one great blow.

THE GUN AND THE TORPEDO

In none of these features is either of the other weapons likely to overtake the gun. The torpedo relies mainly upon stealth, the ram mainly upon a happy chance for effective use. Both stealth and chance have their place in war; stratagem and readiness, each in place, may contribute much. But the decisive issues of war depend upon the handling of masses with celerity and precision, according to certain general principles of recognized universality. Afloat, such massed force, to be wielded 386
accurately and rapidly, must consist of units not too numerous because of their smallness—as torpedo craft would be—nor too unwieldy because of their size. We may not be able to determine yet, in advance of prolonged experience of war, just what the happy mean may be corresponding in principle to the old seventy-four, but we may be reasonably sure that it will be somewhere in the ranks of the present battle-ships; and that in the range, accuracy and rapidity of their gun-fire—especially when

acting in fleets—will be found a protection which the small vessels that rely upon the torpedo or ram alone will not be able to overcome, though they may in rare instances elude.

Concerning the frigates and sloops of our predecessors, their place is now taken, and their duties will be done, by the classes of vessel known generically as cruisers, protected or unprotected. The protection, the defensive element of strength, has reference mainly to the engines, to the motive power. The battery, the offensive factor, tends upon the whole to revert more and more to the development of fire, to utilizing the length of the vessel by multiplying the number of guns and diminishing their individual size; and the tendency is increased by the fact that, as such ships are expected to fight only vessels of their own kind, their probable target is penetrable by light guns. Speed is the great element in the efficiency of cruisers, and whatever the speed in smooth water, a great advantage inures to larger ships in heavy winds and seas. As for "armored" cruisers, of which there are many, they belong rather to the class of battle-ships than of cruisers. Whatever the advantages of the particular ships, the name suggests a regrettable confusion of purpose, and, in practice, a still more regrettable departure from homogeneity.

A. T. Mahan.

389

LITERATURE

“Time and space,” a noble philosopher has observed, “are but hallucinations.” It may be so, and from the point of view of the metaphysician ours may have been merely a “so-called nineteenth century.” Certain it is that to judge literature in blocks of centuries is to make a convenient but illogical cross-division. The early, and perhaps the most important, literary influences of the century were in existence long before 1801. Thus, if we look at whatever is now called *fin de siècle*, at violent antagonism to tradition and convention, at discontent of every sort with everything—with rank, wealth, morality, law, marriage, the family—we find that this passion was as noisy and self-complacent a hundred years ago as it is to-day. The French Revolution was the lurid playground of “New Women,” full of what they supposed to be new ideas. The German drama of 1780–1800, now best remembered by the parody called “The Rovers,” in the *Anti-Jacobin*, was replete with the humorless paradoxes and strained situations of Ibsen. The shortest way to an understanding of the antiquity of our “new ideas” is, in fact, a study of the Poetry of the *Anti-Jacobin*.

Romance, again, as far as romance depends for her effects on desperate deeds, on the rhetoric of noble brigands, on the phantasms of the sheeted dead shivering down dark passages among skeletons, on clanking chains, and on distressed damsels, was as much alive in the end of the eighteenth century as at any age of literary history. Goethe, Schiller, Bürger, Mrs. Radcliffe, all following in the Gothic 390 wake of honest Horace Walpole and his *Castle of Otranto*, were preparing the ground for Scott and Dumas. Once more the old “popular” elements so necessary to literature (which, like Antæus, regains vigor on touching mother-earth) had been wholly absent from the poetry and prose of the last reigning Stuart and of the first two Hanoverian kings of England. But, about 1770–1780, literature had returned to its archaic popular sources. Percy had made *volks-lieder* fashionable, Fergusson and Burns had revived the rustic muse of Scotland, and Macpherson had given mankind a draught, though an adulterated draught, from the cup of the sorceries of the Celtic enchantress. In opposition to the urban self-restraint and contented complacency of the Augustan age, Rousseau had preached the pleasures of virtue, sentiment, and of a “blessed state of Nature”; young Werther had gotten him a stool to be sad upon, like Master Stephen: weeping was the mode. Rousseau, as Mr. Pater once observed in conversation, was “the grandmother of us all,” and as tearful as Mrs. Gummidge in *David Copperfield*. Meanwhile the “emancipation” born of science had set in; people thought they knew all about everything; the elder Darwin could explain the universe without a God, quite as easily as any modern Darwinian, if not so elaborately. He may not have been always correct in his theories and facts, still, there they were, and they were “emancipating.” Yet, far from being laughed out of court by the gratifying progress of science, a more mystical religion and a life more austere had come in from the preaching of Wesley, who was practically the parent of our neo-Catholicism in its varying forms. The “Oxford Movement,” with all the strange after-symptoms which it has left behind it, is directly descended from Wesley. Thus romance, sentiment, freedom and variety in poetic form, philanthropy, 391 revolt against the past, return to and reverence for the past, scientific doubt, weariness of life, love of nature, wistful belief, relapse on the forms of the Church, and everything else which stamps the literature of the nineteenth century were alive and active in the last half of the eighteenth century. The year 1801 made no sudden break. The nineteenth century merely went on evolving the principles, revolutionary or reactionary, of the last half of the eighteenth century.

Thus Crabbe, the precursor of whoever, Englishman, American, Frenchman, or Slav, has written of the sombre tragedies of the poor, was born in 1754. Blake, whose perfectly un-Augustan rhapsodies and mystic lyrics were made fashionable about 1870, was born in 1757, out of due time, for his best side is Elizabethan in quality. Burns, born in 1759, is as much at home in the nineteenth century as Tolstoï, while Godwin could not be more “advanced,” or Mary Wollstonecraft more of “a New Woman,” if the former belonged to our “Forward Liberals” and the latter perorated at congresses of her sex. The first twenty-five years of Miss Austen belong to the eighteenth century; yet, except for a certain "old-fashioned" primness of style, she is the first, and, beyond all doubt, the greatest of all nineteenth-century "realistic" novelists of domestic life. For, though a "realist," she is a humorist, and the combination is almost unexampled. Your common realist is a gloomy thing, with no more sense of the comic than M. Zola.

Of the new poets, revolutionary in metre and matter, Wordsworth, Scott, Coleridge, and Southey were born in 1770–1774; they were mature before the nineteenth century dawned. His northern home, among the hills and lakes, fitted Wordsworth to be the austere and mystical poet of nature and of man in relation to nature. Born a poet, his genius was determined by his environment, while his ardent 392 sympathy with the Revolution at once turned his attention to the unregarded poor, and inspired his not wholly successful attempt to shake off the trammels of Augustan "poetic diction," the survival of the Latinism of Boileau and Pope. Later, of course, Wordsworth became the Tory, the patriot, the Churchman, and the Stamp Collector. But his poetical creed he never consciously changed, though he often lapsed from it unconsciously. If Scott was to be a poet at all he was fated to be influenced by the New World, not in its emancipated ideas, but in its wistful return to the Old World of reivers, spearmen, claymores, goblin, ghost, and fairy. The Border ballads lulled his cradle and were the joy of his childhood and manhood. All tradition murmured to him her charms of Border and Highland legend; every ruined abbey and castle had its tale for him; to Ettrick and Yarrow he needed not to say, like Lady John Scott, "Have you no message for me?" He never had a touch of the Augustan horror of mountain and torrent, never a touch of the Augustan contempt of "Barbarism." Walpole's *Castle of Otranto* and Mrs. Radcliffe's novels of terror went to the molding of his genius, as the novels of Miss Edgeworth (born 1767) suggested fiction about the lives and manners of his own people. In his return to the past he came, like Lamb, on the Elizabethan drama, and, unlike Lamb, on the unpublished documents of the Tudor age, the age of desperate resistance to England. But Scott would never have been exactly the poet that he was if he had not heard "Christabel" recited. "Christabel," the entirely original utterance of a genius which, at first, was a child of the enlightenment of the eighteenth century. The early ideas of Coleridge were the ideas of Rousseau and of Bernardin de Saint Pierre, who was, like Coleridge, but more energetically, a seeker for an ideal land where pantisocracy might 393 flourish and a clown might be the poet's "brother."

In poetry, in poetic form, Coleridge was the real and daring innovator, inspired by the eighteenth century reaction against convention, and played on like an æolian harp by every wind of his mystic spirit. His reaction was too violent even for Lamb; his originality too extreme even for Wordsworth. In him, of all our later poets, the "unconscious self" was the strongest and the most free, and of all our poets he had the hardest battle with the dull Augustan survival in such critics as Jeffrey. To them all the ripened fruit of the blossoming time of the late eighteenth century, the poetry of Scott and of Wordsworth, was but dimly intelligible, but Coleridge was the most unintelligible of all. From the Germany of the late eighteenth century came one of Scott's springs of poetic action; from the *Lenore* of Bürger (a popular ballad rewritten) and from the *Götz von Berlichingen* of Goethe. These were the days when Scott longed to possess a skull and cross-bones, and in a love-letter dilated on his choice of a sepulchre. But what came to Coleridge from Germany was the late eighteenth century's reaction against the truly "common-sense" ideas of Hume, the philosophy of Kant, Schelling, and Fichte. In this field, too, he was unintelligible (and no wonder), but he was but adapting the ideas of 1770–1800, and the neo-Hegelians of Oxford are doing the same thing. A reaction against the materialism of common-sense was inevitable; Mesmer, Swedenborg, and Kant began what survives in the hands of the Master of Balliol and of Professor William James.

In a more recent generation Byron prolonged the Wertherism of Werther, Byron being thus a grandson of Rousseau, while he borrowed his form, and borrowed it very ill, from what Scott borrowed of Coleridge. The genius of Byron is not contested by the sane, but except in satire it seldom 394 found clear and adequate, because it sought hurried, heedless, and tumultuous, expression. Scott had a better ear and was not so reckless an *improvisatore*. Poems that can endure are not written like Byron's, in the brief leisure of fashionable industry. We admire the native impetus of Byron, his gift of satire, his sensitiveness to elemental force in nature and in man, but we cannot understand the furore which was so much the child of his title, his beauty, his recklessness, and his studiously cultivated air

of mystery. Mr. Lenville, as reported by Mr. Folair, said that Nicholas Nickleby was “a regular stick of an actor, and it’s only the mystery about him that has caused him to go down with the people here, though Lenville says he don’t believe there’s anything at all in it.” A later age must partly adopt the same theory of Byron’s original and unparalleled success in Europe as well as in England. He was mysterious Manfred, he was Childe Harold, he was the Corsair; a hero of Mrs. Radcliffe’s, with an Oriental air and a gloomy secret and a heart burning with indignation against the unworthy species of men. What had Byron done? Even Goethe was curious, believing wild anecdotes; now we really do not care what Byron did, recognizing in him, his genius, and his pose, not so much the “Satanic,” as the result of hysteria and madness in his race. Satanism, from of old, has been mainly hysteria. The element of personal *reclame* in Byron has faded, and with it fades his reputation as an earth-shaking poet. Attempts to revive that fame in our day, attempts to bring us back to “the noble poet,” are respectable, being based on loyalty to the taste of our great-grandfathers and grandmothers in all civilized countries. But the efforts are futile. “Byron,” says Mr. Saintsbury, “seems to me a poet distinctly of the second class, and not even of the best kind of second, inasmuch as his greatness is chiefly derived from a sort of parody, a sort of imitation of the qualities of the first. His verse is to the 395
greatest poetry what melodrama is to tragedy, what plaster is to marble, what pinchbeck is to gold.” Such, however unpopular they may be, are my own candid sentiments, for though from childhood I could and did read all our great poets with pleasure, it was not with the kind of pleasure which Byron in his satire and his declamation could occasionally give me. He is monotonous, he is rhetorical, his versification is often incredibly bad, and he is more obscure, mainly by dint of hurry, bad printing, and bad grammar, than Mr. Browning. Thus Byron leaves us impressed as with a vast, even volcanic, yet dandified force, untrained and often misdirected. Either by nature, or in reaction, he professed sympathy with the Augustan school of Queen Anne’s reign, and sided with Pope in the long quarrel as to whether Pope is a poet.

Even the modern opponents of Byron must recognize in him qualities which won the admiration and affection of Scott and Shelley. In Shelley we had a true child of the revolution, the *Aufklarung*, and the later eighteenth century. His boyhood trifled with chemical science (probably not then popular with the human boy); his adolescence was given to converting school-girls into “dear little atheists.” His social ideas, like those of some advanced moderns, aimed at the absolute destruction of the family; and the moral of *Laon and Cythna* went far behind the morals of the most backward savages, who make incest a capital offence. Shelley, a boy all his life, was more boyishly devoted to destruction than even the newest writers on the relations of the sexes. In “making all things new” both he and they are, in fact, relapsing on a condition of society which, if it ever existed, is so old that it may be called “pre-human,” and is contrary to nature, as far as we can study human nature in the least developed of tribes. 396
His ideas conducted Shelley to the tragedy and farce of his career: his desertion of one young wife, followed by her suicide, and his marriage with another, in entire opposition to his own opinions. In literature he began at school with a devout following of Mrs. Radcliffe; while, in *Queen Mab* and *Alastor*, vigorous but vague and misty *Childe Harold*, wandering in No Man’s Land, he first displayed his originality in poetical form. His personal character being noble and generous in the highest degree, his sympathy with the poor and the oppressed being a true passion, Shelley’s errors arose from the fixed idea that almost every human ordinance must, being old, be necessarily bad. He would recognize that there is, after all, something right in the sixth commandment, but did not draw the inference that a gleam of reason might also be found in most of the rest of the Decalogue. The state of society then, as always, provoked revolt, but the state of society was grievous, not because its moral laws were bad, but because its laws were not obeyed. Shelley had no turn for narrative, and, in such poems as *The Revolt of Islam*, it is the splendid meteoric genius, the unexcelled music that captivate. In lyrics he was probably the most original force since the Elizabethan age: his verse is a singing and soaring flame. In *Adonis* his righteous indignation carries him forward like an angel with a sword of fire; and *The Witch of Atlas* is a triumph in a new “fairy way of writing.” His is the Muse of clouds and stars, of sea and tempest, of all the aspects, and, in appearance, most capricious forces of the world, yet his is also the Muse of flowers and peaceful woods, of dejection and of delight. What the born rebel, Milton, might have been without the foundation and trammels of Puritanism, that Shelley was, though his wild and tender lyric note was even more exquisite than Milton’s. Neither was, in the full sense, human, for 397
both were without humor, as may be seen in their humorous pieces.

Keats, but three years younger than Shelley (1795), was more a true child of the nineteenth century. His social ideas, though of course liberal, were more in abeyance; he was more exclusively an artist; and his art was more controlled by the revived Elizabethanism of Leigh Hunt (1784). That singular man, who had so much taste, and so much of it bad; so intense a theory of social benevolence, and so keen a belief that it was more blessed to receive than to give, "owed little" (in the way of literature) "to any but the old masters, and many contemporaries owed not a little to him." Few owed more, for good and bad, than Keats. Virgil he had found out for himself, and had translated when a schoolboy. Spenser, too, he found for himself, and Greece he discovered afresh in Lemprière's *Dictionary* and in Chapman's *Homer*. But this superficial euphuism and elaborate verbal quaintness he partly derived at second hand from Leigh Hunt.

That something in Leigh Hunt which suggested Harold Skimpole to Dickens, and his violent conception of *The Cockney School* to Lockhart, was not hidden from Keats, and inspired him with some bitter words. It was what he derived from Hunt that gave occasion to Keats's assailants, who were more of political than of literary partisans. Lockhart, or Wilson, or both, with the *Quarterly* reviewer, in attacking *Endymion* were attacking, they thought, a member of an affected, effeminate, and radical coterie. Keats himself, maturing with the suddenness of genius, looked on *Endymion* as thoroughly immature. But killed, or even discouraged, by his critics he was not, and on a page of a copy of *Lamia* where his publishers spoke of his discouragment he wrote "This is a lie." (The copy is in the possession of Canon Ainger.) Keats, like Burns, whom he so intensely admired and so 398
unerringly judged as a man and a poet, was his own best critic. Despite his boyish lusciousness of taste, and the fever of letters written when dying, there was no manlier or more chivalrous soul in England than that of the poet of the odes to the nightingale and to autumn. Keats at his best attained sheer perfection of language, of emotion, and of thought. As he advised Shelley to be, he was not content with less than filling all the rifts with pure gold. "Untaught," like the minstrel of Odysseus, he combined a Greek clarity and largeness of manner with that romance which Greece does not lack, but which he possessed in a degree more conspicuous, at least to readers who are not Greeks. Though he has not been and cannot be imitated, he has supplied to Tennyson and the best moderns a standard and an ideal. That the Shakespearian copiousness of humanity and humor and dramatic genius would ever have been his nothing indicates, but what writer of the nineteenth century, except Scott, has possessed a large share of these qualities? In poetry, not one, and it was in prose that Scott wore his fragment of the cloak of Shakespeare. For the century has not produced, in England or America, a great dramatic poet. It is to fiction, to Scott, Dickens, Thackeray, Stevenson, Meredith, Hawthorne, George Eliot, that we must look for the humor and humanity and passion which, earlier, found their vehicle in the drama.

Ours is a reading rather than a seeing century, though this does not explain the reason which made the great novelists incapable of writing for the stage. Of the other poets of the early century, Campbell, Rogers, Moore, Landor, Hogg, and the ladies, Mrs. Hemans, and L. E. L., and Beddoes, space does not permit us to treat. Landor's audience has not increased; Rogers has none; Campbell is best remembered for war songs which I fear are overrated; Hogg, despite some exquisite passages in *Kilmeny*, and some admirable songs, suffers from his countrymen's exclusive devotion to Robbie 399
Burns. When Scott turned to fiction (1814) the current of popular taste at once changed into that channel. Byron had still his vogue; Keats, Shelley, and Coleridge then sang only to the few initiated; Wordsworth was past his prime; and with the general public nothing was really popular but fiction, and that fiction was Scott's. Miss Austen is probably much more widely appreciated to-day than when she died, little noted by the world, in 1817. A criticism of Scott's novels, which first made fiction supreme and far above poetry in the estimation of "the reading public," cannot be attempted in this place. The best estimate of Scott, if far from most favorable, is his own, in the introduction to *The Fortunes of Nigel*. His faults of prolixity, haste, indifference to delicacy of style, and even to grammar; his "big bow-wow" vein (as he calls it); the stilted theatrical language of his Catherine Glovers and Helen Macgregors—all these defects, with his hasty denouéments (as of Shakespeare and Molière), are patent, are confessed, and probably deter many readers from making profit of his humor, his rich knowledge of and sympathy with all human nature, his infrequent but exquisite touches of passion, his tragedy and comedy. None the less, Scott is the main stock of the fiction of the century. Men may now have more minute knowledge, though so wide a knowledge has none; may have more wit, if less

humor; may eagerly hunt for all that Scott loathed and avoided in our animal nature; may, indeed must, practise a more careful style, but all the novelists are, willy-nilly, children of Scott and Miss Austen. Dickens, indeed, owed more to Smollett (one of Scott's chief favorites), Thackeray owed more to Fielding, the "Kailyard School" owed more to Galt (1779—1839). But Scott is "the father of the rest," above all, of Dumas; and Miss Austen is the mother. Lord Lytton and Mr. Disraeli had, especially at first, a tinge of Byronism, later developing on their own lines: Mr. Disraeli's political; Lord Lytton's multifarious, including the line of modern mysticism, now often worked. Scott lived to be interested in Lytton, and might have seen (though probably he did not see them) the little-noted beginnings of Browning and Tennyson, about 1830. 400

What he did see, and admire, was the performance of Cooper, with whom actual and living American fiction may perhaps be said to take its rise. In England, Cooper was regarded as the Scott of America; and it is to be regretted that Lockhart did not excise a splenetic personal reference to Cooper in Sir Walter's *Journal*. He was old, tired, and fatigued with the pressure of society in Paris when he wrote. Cooper had the genius to appropriate the unworked fields of American patriotic seafaring life, and of the manners of the Red Man; he is "Cooper of the wood and wave." Eagerly were his works read by boys, when Thackeray was a boy, and when I was a boy. Never shall his readers forget the "Long Carabine," to whom Thackeray was devoted, and Uncas, and Chingachgook.

"Still we love the Delaware,
And still we hate the Mingos."

Doubtless Cooper's Indians are not "realistically" treated, though there is infinitely more of truth in his dignified hunters and warriors than people conversant only with the Red Man of to-day are ready to believe. But Cooper, probably, does not live with the immortality of his first renowned successor, Hawthorne, who, for secure perfection of form, is to modern fiction what Keats is to modern poetry. Like Scott, Hawthorne is the unforced fruit of his ancestry and the society into which he was born—a Puritan, not a Cavalier artist, with a background of austere faith and of old superstition, differentiated from that of the Covenanters by the shadow of deep forests and of struggles with the Indians and the wild things of the woods. These had passed into mellow memories, as, for Scott, had passed the age of witches, fairies, reivers, and claymores. Entirely, in the *Scarlet Letter*, as by way of hereditary influence in the *House of Seven Gables*, Hawthorne reproduced what was old, making it poetically enduring. *His Mosses from an Old Manse*, and other brief tales set the fashion, except by Poe, long unfollowed, of the *conte*. Neither author has been excelled in his own portion of this field. Hawthorne's haunted consciences, Poe's treasure tale, his detective stories, and his tales of terror remain unequalled, though so profusely imitated. This epoch, say from 1830 to 1855, was a kind of classical interspace in the literature of the century. France, preoccupied by war in the first thirty years of the age, now awoke to her own famous romantic era, with Hugo, Dumas, Musset, Gautier, George Sand, Sainte-Beuve, Mérimée—names of the highest. Germany, to the non-Teutonic world, is, in poetry, represented by Heine, and, in science, philosophy, philology, and history by a galaxy of innovators ingenious and industrious. America saw Hawthorne, Poe, Lowell, Holmes, Whittier, Ticknor, Prescott, Motley, Longfellow, Bryant, Emerson, in their prime; while England had Carlyle, Tennyson, Newman, Browning, the Brontës, Kingsley, Thackeray, Dickens, and Ruskin, all recognized and flourishing. 401

We look around and see, as Mr. Stevenson says in a letter, that "the suns have set," while we are scarcely conscious of new dawns. Who can explain, by circumstances of social evolution and historical event, the rising and the setting of such constellations of genius? It is not enough to speak of the democratic demand, naturally indifferent to style, for never was style the object of such anxious research, except in other ages of euphuism. Encouragement is even overabundant; "masterpieces" are announced every week, and forgotten every year. It may be the prejudice of hoary eld, but I must confess that our new literature does not seem to me to show such promise of permanence as the literature of 1830–1860 gave, and, so far, has fulfilled. Has fulfilled in spite of our sneers at the "early Victorian," which was not socialistic, or evolutionist and Darwin-ridden, and was "respectable," and did avert its eyes from all that most people in real life don't care to stare at. This "prudery" was no new thing. The Greeks, in except some late decadents and in the old comedy, have a "prudish" 402 literature. The Latin classics are not in the taste of M. Zola. The age of Chaucer, the age of Elizabeth, were grossly frank, that of the Restoration was frankly lewd, but we have sought out many inventions over which Sedley and Rochester would not have cared to linger. Their grossness was gay; ours is morbidly squalid. Such things are absent from the work of Hawthorne and Holmes, Longfellow, Dickens, Thackeray, and the rest. Such things we now treat of, greatly daring, and somehow our elders appear apt to outlaugh and outlive us as humorists, novelists, and poets. It is strange.

Into the merits of that remarkable middle age of the century we cannot enter in much detail. Tennyson holds unimperilled the throne of the poet of the time. That his thought is not especially penetrating, whether he deals with the intricacies of human character, or with the problems of the universe, may be readily admitted. But I am unaware that any poet has yet “got the absolute into a corner,” or solved the problems of the universe. Tennyson, more than people suppose, was, personally, a mystic, with his own mystic experiences; and his philosophy was influenced by them. He “followed the Gleam.” Neither in the *Idylls of the King* nor in plays, was dramatic rendering of character his 403
forte. His forte was charm, and music, and the interpretation of nature. In these he is the equal of the Mantuan, is the Virgil of the modern world, “golden branch among the shadows.” Moreover, he has infinite variety: from *Mariana* to *Fatima* and *Rizpah*; from the *Lotos-Eaters*, which “adds a new charm” after the *Faërie Queene*, to the *Northern Farmer*, from *Ulysses* to *Crossing the Bar*. The early *Morte d’Arthur* is of unsurpassed nobility and magic; the last poem, *Crossing the Bar*, is no less pre-eminent in these qualities. Tennyson, in short, had genius; new, as all genius is new, and no occasional defects of taste or temper can impair the splendor and richness of his gift to the world, nor the immortality of his fame.

His contemporary, Browning, had the misfortune to attract, by his faults, the people who wish to believe themselves clever, because they labor at appreciating passages which the poet had made obscure. Darkness is not depth, nor is obscurity a merit. From his letters it is plain that Mr. Browning had not the gift of lucid expression; from his poems it is manifest that he had not, in a high degree, the gift of verbal music and of charms. His gift of the grotesque, very real and original, was also his snare. In *Christmas Eve* and *Easter Day*, with *Men and Women*, we have the true essence of Browning at his best; we have his dramatic lyrics, with their amazing abundance of character and variety of measure. After the first fascinating volume *The Ring and the Book* became monotonous. One song in *Paracelsus*, to myself, seems worth all the dissection of character in the blank verse. There are many who find a kind of spiritual help in such pieces as *Prospice*. There are thousands who find in *Men and Women* a sort of intellectual enjoyment (or entertainment) which they can derive from no other poet who ever lived. An energy, life, and sympathy, breaking forth in fresh, unheard-of ways; vocal in 404
strange, piercing, untried measures: these are the imperishable qualities of Browning. Look at his rendering of the Agamemnon: such is his version of life. The poetry of Æschylus is not there: “*carmina desunt*”; but there is a new, odd, unexpected rendering of the tragedy. So poignant and broken, sad, glad, grotesque, and pitiful, was Browning’s rendering of life. He was “ever a fighter”: no poet is more exempt from whining and despair. Destiny linked him with Mrs. Browning, whose genius, sincere and original, is apt to be obscured by palpable faults of manner, emotion, and even rhyme, on which it is superfluous to dwell. Her merits, and some of her defects, made Mrs. Browning the most popular of women poets in England, except, perhaps, Miss Ingelow. Both, in the crowd of accomplished versifiers, appear as true poets, though both, no doubt, fail to reach the place of Miss Christina Rossetti, who never can be popular.

The matter of popularity is full of puzzles and paradoxes. Tennyson was popular, yet great because he is popular. There was a moment when popularity without permanence might have been expected for Longfellow. The excellence of his moral intentions was then more obvious than the poetry. Such early pieces as *Excelsior* and *The Psalm of Life* yield odd results on analysis. But not much better can be said for the *Queen of the May*, and for parts of *The Miller’s Daughter*. In these is a marvellous dexterity in sinking. But sink, and remain sunk, was as little characteristic of Longfellow as of Tennyson. He was a true poet, in his lyrics, even in his translations, as well as in *Evangeline*, and that excellent experiment *Hiawatha*, where the measure of the Finnish popular poems is applied to the not dissimilar legends of another woodland race. But Longfellow lacked that undefinable quality of the 405
rare, the strange, the hitherto unheard yet delightful note which now and again is heard in the verse of

Edgar Poe. He was an Ishmaelite in literature, his hand against every man's hand, and hence seems to be less admired where he was personally known than in France and England. It is not the famous *Raven*, but such pieces as *To Helen*, *the Sleeper*, and at most a dozen others which give Poe his high place in the judgment of his admirers. Not his ideas, but the beauty of his haunting lines, confers on him the laurel. Of Bryant, as a rule, and of Whittier almost always, the reverse is the truth. The acceptability of their ideas, the refined simplicity, not the natural magic, of their form, are their claims to renown. Except in a few places, as in such as his *Commemoration Ode*, Mr. Lowell is better remembered for the wit and vigor of his Biglow poems than for his serious verse, at least in England; while Emerson's prose has precedence here over his poetry. The wisdom of the East and West, blended with his happy, courageous temper, made Emerson a corrective Carlyle, while Thoreau is the complement of Emerson.

Concerning the great Victorian novelists, Thackeray and Dickens, so much is daily written that remark is superfluous. A master of observation of all that had rarely been observed, a generous heart, an original and abundant humorist, the greatest source of mirth in our century, Dickens appears to wear less well than his rival. The unapproached merits of Thackeray's style must preserve him in literature; his pathos is rare and unforced; his form of humor is as permanent as that of Fielding, and as successfully matched by his phrasing. Even his verse, mirthful or melancholy, does not fade, and has its own place on the borderland of poetry. George Eliot's fame, too, must revive the success of her earlier and more humorous novels, before she became too fond of the Spencerian philosophy, and took herself too seriously, a natural result of adulation. Charlotte Brontë, in the same way, has been, as it 406 were, rediscovered amid a chorus of fresh applauses, and with perhaps rather too curious investigations. In America, after Hawthorne, Dr. Oliver Wendell Holmes and Mrs. Beecher Stowe were the novelists most generally admired in England, when Thackeray and Dickens were verging to their decline. It is, indeed, to be regretted that Dr. Holmes did not write more fiction when in his prime. His excellent and original *Elsie Venner*, and *Guardian Angel*, with their humorous pictures of real life and their thread of phantasy, half mystical, half scientific, border (as often in the *Poet* and *Professor at the Breakfast Table*) on the ground of "psychical research." Dr. Holmes was not merely, in verse and prose, an exquisite wit, but a man of rare knowledge, a man of science, and a sturdy defender of the purity of the language. Mrs. Beecher Stowe, on the other hand, took the world by storm with a vivid tract in the form of fiction; a book now not easy to criticise, but which can still move to laughter and tears. It is my "insular ignorance" which prevents me from appreciating other American fictions of that age, before the days of writers still happily living and working: Mark Twain, Bret Harte, W. D. Howells, Henry James, and scores of others, who, being here to speak for themselves, shall not be commented upon in this place. With Mr. Howells, as a critic, I have tried to break lances, while ready to admit one of his main contentions, that the art of Scott, Thackeray, Dickens, and others of our fathers would have profited much by being a finer art, by condensation, by omission, by avoidance of the superfluous. But that our modern fiction is a greater art, that romance and story-telling and adventure are obsolete, or ought to be obsolete, that I can never admit while human nature is human nature. Mankind will never be content, in fiction, with tales of the psychology 407 of the ordinary person; ordinary as we are, we desire to be, like Homer's Heracles, conversant with great adventures. Mr. Howells perhaps may think Aristotle a Greek snob when he maintains that tragedy must find its theme in the sorrows of the god-descended kings. Are not the griefs of the poor or of the middle classes as poignant? They are; but they do not involve such heights and depths of fortune, raising or wrecking whole states, as do the woes "of Thebes, or Atreus's line." The fall of Prince Charles from an hour even of shadowy royalty, from the leadership of an army, from the wondering admiration of Europe and the applause of Voltaire into the subject and dependent sot is an example of modern historical tragedy; in its elevation and its decline more apt to move "pity and terror" than the circumstance that a journalist has taken to drink.

As in the case of America, so in that of England, I cannot enter into the merits of living novelists in so wide a task as the brief review of a century. Mr. Meredith, as a veteran of the 60's, has shown, perhaps, fully what is the nature of his achievement; he shines as a creator of character (the highest praise) and as a writer with a thoroughly original view of the world, as a poet and as a wit. That his manner is entirely fortunate, and not rather tinged with wilful eccentricities like those of Browning and

Carlyle, can scarcely be disputed. An accomplished young novelist has admitted to me that his manner is “catching,” and that he has to struggle against half-conscious efforts at imitation. Others do not struggle; and most grow older before they are able to write like themselves, with their own voices. Even Mr. Stevenson was caught now and then, his own voice being original indeed, but yet full of memories of the seventeenth and eighteenth centuries, and even of the Cameronian writers. To my mind Mr. Stevenson was the greatest, or, at least, the most enjoyable, of our novelists since George 408
Eliot, excelling in matter and form, though probably always prevented by thwarting circumstances from doing himself complete justice. He practically revived in England the novel historical, now so abundantly practised, and practised with spirit, by Mr. Stanley Weyman, Mr. Anthony Hope, Dr. Conan Doyle, Mr. A. E. W. Mason, and a regiment of followers. The novel scientific, as in the hands of Mr. Wells, and the novel of adventure, “beyond the bounds of known romanticism,” as in Mr. Rider Haggard’s works, with the detective novel and the Oriental and imperialistic romances of Mr. Kipling, prove that man will not be satisfied with domestic realism alone. I never thought he would! Mr. Kipling’s astonishing powers of vision, his habit of ruthlessly cutting the superfluous, and his amazing command of technicalities, help to account for his world-wide fame. But the greatest of these is vision, not an acquired result of thought, but a gift of Heaven. The age has also produced a wealth of novels with a purpose. Would that the authors could be induced to state their purposes squarely, in undecorative treatises! But I confess that the treatises would not be read. The specialism of modern science has also invaded fiction, and some authors find a county or a parish wide enough for the work of a lifetime. The district has its dialect, and who can reprove it when spoken by the creatures of Mr. Barrie and Mr. Crockett? This kind of fiction is the result of our desire to learn (through novels) about the lives of all sorts and conditions of men. *Enfin*, the whole scope of mortal existence is now the *farrage libelli* of the novelists who range from prehistoric man to Bethnal Green; from Thrums to Central Africa. There is not the same eagerness to read history, which James II. regarded as “more instructive, and quite as amusing.” My heart is here with King James, and I confess to gaining more 409
entertainment from Carlyle’s *Frederick the Great* than from most novels.

The earlier historians, from Scott to Carlyle, Macaulay and Froude, placed the human interest in the front rank. They conceived that history had to do with human beings of passions, caprices, moods, loves, and hates, dwelling in a world of interesting costumes, arms, architecture, ideas, and beliefs. Thus Carlyle, with much research, created his Cromwell or his Frederick, as Scott created his Queen Mary, his Louis XI., his James VI., or his Cromwell in *Woodstock*, who is not too remote from Carlyle’s. For these reasons Scott, Froude, Carlyle, and Macaulay really are “amusing” as well as instructive historians. When institutions and constitutions had to be described they were placed in separate compartments, as in the works of Hallam and Bishop Stubbs. Historians studied manuscripts, of course, but it was not held that only the unprinted was the valuable, that a new survey of known matter was absolutely valueless.

In the end of the century we have history which is not “as interesting as a novel” (like that of Prescott, Motley, Froude, and Macaulay), but very far from gay. Novelty of research is, quite justly, insisted upon (though research is as old as Hemingburgh, and was much advanced by Gibbon, Carter, Rymer, Walpole, Tytler, and so on) till, by a natural error, every scrap won from a wilderness of charters is valued beyond its deserts. The human interest is frowned upon; movements of forces, political and social, are treated in preference to personal character and adventure. Meticulous accuracy is insisted upon, till nervous students are actually afraid to publish. Even Mommsen, greatest of original students, is regarded as frivolous, even Curtius as “popular” by the modern school. It is natural to man to run into these excesses of reaction. Froude is not often accurate, Macaulay has 410
prejudices, even Mr. Freeman was not sound about Knights’ Fees and about a certain palisade. Now the public does not care about Knights’ Fees or about the Manor, much; nor even about the obscure early history of civic institutions. In fact, even references to authorities frighten away part of the public, whose timidity I do not applaud. The results of our frivolity and of the portentous gravity of some modern historians is that, since Mr. Green, scarcely any writer of history is read except for examinations. As long as historians declare (often with perfect truth) that their own works are not literature, but something far more awful and solemn, namely science, history must be unpopular. But we are only waiting for a man of genius as accurate as the most meticulous, and as interesting as the

agreeably irresponsible Froude. Of science I am not to treat, so I am dispensed from remarks on our scientific modern historians. It is certain that in collecting and printing and calendaring documents the age in all countries has shown praiseworthy industry, while Mr. Parkman in America, like our mid-century historians, was not too scientific to be readable.

Of theology, except when recommended by the art of a Newman or a Jowett, nothing is here to be said; though I could cheerfully say a good deal, especially about Biblical criticism. But that is science, though scarcely the sort of science which has been defined as "organized common-sense." The poetry of the late century in England boasts the names of Rossetti, William Morris, Matthew Arnold, and Mr. Swinburne. It is tinged, in the former with mediævalism derived from the Italians and Chaucer; while in Mr. Swinburne every conceivable literary influence, from the Greeks to Baudelaire, from the Elizabethans to Victor Hugo, makes itself abundantly conspicuous. These poets, younger than Matthew Arnold, are not much influenced by Wordsworth, though by Shelley Mr. Swinburne was 411 influenced. On the other hand, Mr. Arnold was a modern, academic, heterodox Wordsworth, and often a truly delightful poet.

He stood much aloof from the contemporary literature of his day, and his letters prove that he was no fervent admirer even of Tennyson or Browning. His own poetry has been to many, as to myself, full of delightful passages, whether he wrote of the Oxford country-side, or of Wordsworth's hills, of "the shorn and parcelled Oxus," or of the moaning sea that Sophocles long ago heard as he heard it on Dover beach. He was our greatest modern elegiac poet; a master of the Dirge. Of the living, again, no criticism can be offered; we only note the names, and real if very various merits, of Mr. Robert Bridges, Mr. Watson, Mr. Davidson, Mr. Dobson, Mr. Benson, Mr. Thompson, Mr. Henley, Mr. Gosse, Mr. Stephen Philips, Mrs. Marriott Watson, Mrs. Maynell, Mr. Kipling, "a nest of singing birds." It would be impertinent, and indeed perilous, to "draw invidious distinctions," as the undergraduate said about the major and minor prophets: nor is it for this century to sift the poetic sheep from the goats, who, in an age that reads little poetry, are greatly guilty of much verse.

The unassuming and decried art of criticism remains. Essays are of no one age; there are similar excellences in every good essayist since Montaigne. We have no Hazlitt, Lamb, or Leigh Hunt, but we had Mr. Stephenson and Mr. Pater, so unlike in all but conscious interest in style, and reminiscence of the best models. Indeed, essay writing is almost an unpractised art, as the public "has no use for it," any more than for the letter H on the Sandwich boards. A fairly bad novelist can live; to an appallingly bad novelist the workhouse unfolds its awful valves. In literary criticism Mr. Arnold stood alone in his age, and Mr. Arnold's literary income, it is known, surprised, when stated, the Commissioners of 412 Income Tax: not by its affluence. Of living critics it would be in the highest degree dangerous to say a word, though many words, both of praise and dispraise, might be said of a person of reckless character. That (with obvious exceptions) most critics are men intimately familiar with what is best, from Homer to Mr. Stephen Philips, few students would venture to aver. That we (for am I not the least of all critics, and not worthy to be called a critic?) are entirely devoid of ignorance, personal bias, likes, dislikes, prejudices, pet aversions, indolence, we are not so blindly conceited as to maintain. We have been taught by many centuries of creative geniuses, from Theocritus to the latest protesting popular novelists, to know our proper place, and we take refuge in "confession and avoidance." The new century will not know our names when we pass where Dennis and where Cibber are, unless Mr. Robert Buchanan writes a new *Dunciad*.

The century, even if we are in full decadence (of which we are not the best judges), has been glorious in literature, and holds its own well with any in modern history. English itself has passed from the occasionally stilted Augustan survival, through the novelties of Macaulay, De Quincey, and Carlyle, and the early decorated of Mr. Ruskin, into slipshod slang in one extreme, and euphuism in the other. But the main stream keeps its course, and English may be written with perfect purity, and with new fluency and variety, by the men for whom the task is reserved by fate. But what does the century bequeath by way of intellectual motive? Little but the more or less transformed forces of the eighteenth century. There is science, but science, happily, is beginning to be aware that she is not really omniscient. Conceivably her foot is on the border of a new region, often surmised, never explored, full of light on the problems of spirit and matter. Hence, indeed, might come a new force in 413 letters. Again, the social ideas of 1750–1800 may take practical shapes of incalculable momentousness, but these would not for long be favorable to literature. Or, less probably, the return on the past may assume practical shape, though this element of the later eighteenth century may seem, as far as letters go, to be exhausted. In brief, as I began by saying, the division of literary periods by measures of time is a cross-division. This peculiarity the last hundred years possess: that literature now blossoms on a far wider field. English-speaking America had, indeed, a literature long before the War of Independence; but it was not a literature for every reader of to-day. Now, and for long, the States have taken their own part in history, fiction, poetry, and all other branches of letters. Germany came back into world literature again just at the ending of the eighteenth century, after unregarded ages of neglect. Russia and the Scandinavian North awoke about the same time, and daily widen their influence, as does Belgium in the sunshine of Maeterlinck. France, of course, has in all time been in the foremost rank; while to balance America, Russia, and the North, Italy and Spain have scarcely held the place which through so many centuries was their own. Such changes in national literatures resemble the political waxings and wanings of national fortunes. The English-speaking peoples may have their eclipse; perhaps it is heralded by a modern comparative deficiency in humor which, if England and America cease to laugh, will die out of a profoundly solemn world.

In the foregoing remarks little has been said about the literature of the century except among English-speaking peoples. Not being a Mezzofanti, I am not personally acquainted with the literature of all languages, and it is a vain thing to speak of books at second hand. It was not the nineteenth but [414] the eighteenth century that saw Germany re-enter the field of pure literature, as distinguished from that of scholarship and science. Since the end of the Middle Ages, with their poets, German writers had mainly been devoted to theology and classical criticism. Latin was the language of the learned. Many ascertainable causes, in the middle and end of the eighteenth century, and doubtless many causes which cannot be ascertained, awoke again the Teutonic genius. The victories of Frederick the Great gave Germans patriotism and confidence in their own tongue.

The philosophic and social works which preluded to the French Revolution stirred the German mind and required popular expression. Thus Kant wrote in his own native speech in reaction against the sceptical philosophy of David Hume, and Kant became the father of the long array of German metaphysicians from Hegel and Fichte to Schopenhauer and Hartmann. Their philosophy “cannot be briefly stated, especially in French,” as one of them said, but its general effect has been rather to counteract materialism by making it pretty plain that human nature is not so simple and easily to be explained as the Scottish philosophers were apt to suppose. In England, Coleridge gave an Anglican heart to the new German philosophy, which also influenced Hamilton, and still affects the philosophical teaching of Oxford. “It is nonsense, but is it *the right sort* of nonsense?” asked the late Professor Sidgwick (a Cambridge man) when struggling with the examination papers of a Hegelian undergraduate.

More important as literature were the double influences of return on the mediæval past and of inspiration by the new political and social ideas which gave the impulse to the genius of Goethe, Schiller, Bürger, and others. Goethe began as the child of Rousseau, but as a child who had read Kant, [415] and drunk deep of the romance of the Middle Ages. Doubtless his is the greatest name of modern Germany, both as a student of life, of nature, of history, and of thought. He was the spiritual parent of Scott, with his *Götz von Berlichingen*, and, with Richter, of Carlyle. Through himself and his English or Scottish disciples, Goethe has been the most fertile source of change in the literature of the nineteenth century. In extreme old age, curious to say, he gave the first impulse to the study of early religion as displayed in the obscure rites and beliefs of the Australian natives: a theme remote enough from his effect on the poetry of Matthew Arnold. Probably the two parts of his *Faust* and his *Roman Lyrics* are the most popular, and, as literature, the most permanent parts of his work, with *Werther*, *Wilhelm Meister*, and *Elective Affinities*, in prose. Schiller, beginning with the boyish romanticism of *The Robbers*, became a kind of classic in his later dramas. Lessing and Winckelmann were the most sound and fertile influences in criticism. *The Laocoon* remains indispensable. The patriotic lyrists resurrected the national spirit of the Teutonic race, and Heine, Hebrew by race and half French in character, combined the characteristics of Lucian, Burns, and Voltaire.

Wolf, writing in Latin (and I believe that his work on Homer has never attained a third edition, and has never been translated into English), became the parent, for good or evil, of what is called the Higher Criticism, Lachmann introducing the painfully conjectural tendencies of that intellectual exercise. Its application to scriptural texts is notorious, but not precisely as part of literature. Like other European countries, the Germany of the close of the century is not remarkable for resplendent genius in poetry or fiction, though novels abound. The scientific, historical, and scholarly literature is of vast 416 profusion. In thoroughness and tireless patience, Germany is the teacher of the world, while in curious contrast to her practical genius is the love of some of her scholars for baseless conjecture. The "insularity" with which the English are charged is a matter of reproach by French scholars against Germany. Some sets of ideas, long familiar in America, England, and the Latin nations, are only now beginning to reach German classical scholars.

To write an account of the changes in French literature during the century is impossible within moderate space. The revolutionary and Napoleonic wars were unfavorable to the literary art, and the head of so great a poet as André Chénier fell under the guillotine. Till about 1825–1830 the Restoration was accompanied by literature in the old classic style of Boileau and of the Augustan age, only enlivened by the romantic if somewhat affected style of that great rhetorician, Châteaubriand. The year 1830 is the sacred year of French romanticism, drawing its ideals partly from the German romantic movement, partly from Scott and Shakespeare, read, of course, only in translations. Everything was now to be mediæval, Spanish, and passionate: the drama was to be emancipated from Aristotle, also read in translations. As far as classicism went the young adventurers had no more Greek than Shakespeare or Scott. But they had the colossal and Titanic genius of Hugo, exquisitely sweet, rapid, strange, and versatile in lyric: potent, if inflated, in the drama and the novel. They had the charming humor and exquisite taste of Théophile Gautier; the feverish passion and mastery in verse of Alfred de Musset; the delicate, dreamy, and wandering spirit of Gérard de Nerval; and the manly, courageous, humorous, and unwearied vigor, in drama and in fiction, of Alexandre Dumas.

This was, indeed, an extraordinary generation, by far the greatest since that of Corneille, Racine, 417 and Molière. Many others might be named: the reserved force and incisive irony of Mérimée; the learned and genial criticism of Sainte-Beuve; the inexhaustible talent of George Sand, and the mighty Balzac, the maker and founder of the modern work of introspection. Probably, of all these writers, Dumas and Balzac have exercised most influence on later fiction in England and America. Flaubert continued, with painful elaboration, the traditions of Balzac; from Flaubert, and round him, grew up Daudet and M. Zola, and the Goncourts. Poetry, after Lamartine, dwindled into the prettinesses of the Parnasse and the eccentricities, too obviously intentional, of Baudelaire, Verlaine, and the Symbolistes. Literary art, at the end of the century, became too self-conscious, too fond of argument about ideals and methods, the tattle of the studio. Great men have not thus dissipated their energy; they have done what they could do; they have not talked about how they did it. What English literature was borrowed from France, at this time, is more in the nature of words than work. Criticism has been a *chimaera bombinans in vacuo*, chattering about realism, naturalism, symbolism, the use of documents, and so forth. The defects, rather than the merits, of France have been imitated; a squalid pessimism is easily affected.

The closing century has seen Russia awake, as the close of the eighteenth century beheld the literary revival of Germany. Russian poetry has only reached the learned among us: the novels of Turguenieff, Dustoiefsky, and Tolstoï are read in translation, with curiosity, antipathy, enthusiasm, and an absence of that emotion. It is very long since Terentianus Maurus remarked that the fortunes of a book depended on the taste of the reader. Often he is favorably impressed, not by the actual merit of the story as a story or as a work of literary art, but by its appeal to his private sentiments, as of 418 socialism, pessimism, toryism, or whatever they may be. Possibly the vehement admirers of some Russian writers have been thus misguided. In any case, no qualified critic thinks that his opinion of works which he cannot read in the original language is of any value. For this reason I need not offend or please the reader by offering any uninstructed sentiments about the great Scandinavian dramatist, Dr. Ibsen; or concerning the work of Signor d'Annunzio, or the plays of M. Maeterlinck. To pronounce each of these gentlemen a Shakespeare or Æschylus is not unusual in cultivated circles; it remains for the new century to ratify or quash the verdict. In the mean time, have the approving critics taken the precaution of reading Æschylus and Shakespeare?

Andrew Lang.

421

ENGINEERING

The material prosperity of the last century is due to the co-operation of three classes of men: the man of science, who lives only for truth and the discovery of nature's laws; the inventor, eager to apply these discoveries to money-making machines and processes, and the engineer, trained in mathematical investigation and in knowledge of the physical conditions which govern his profession, which is the mechanical application of the laws of nature.

Engineering is sometimes divided into civil, military, and naval engineering. The term civil engineering, which will be here described, is often used by writers as covering structural engineering only, but it has a much wider meaning.

The logical classification is: statical engineering, including that of all fixed bodies, and dynamical, covering the movement of all bodies by the development and application of power.

Statical engineering can be again subdivided into structural engineering, or that of railways, highways, bridges, foundations, tunnels, buildings, etc.; also, into hydraulic engineering, which governs the application of water to canals, river improvements, harbors, the supply of water to towns and for irrigation, disposal of sewage, etc.

Dynamical engineering can be divided into mechanical engineering, which covers the construction of all prime motors, the transmission of power, and the use of machines and machine tools. Closely 422 allied is electrical engineering, the art of the transformation and transmission of energy for traction, lighting, telegraphy, telephoning, operating machinery, and many other uses, such as its electrolytic application to ores and metals.

Then we have the combined application of statical, mechanical, and electrical engineering to what is now called industrial engineering, or the production of articles useful to man. This may be divided into agricultural, mining, metallurgical, and chemical engineering.

Surely this is a vast field, and can only be hastily described in the sketch which we are about to give.

STRUCTURAL ENGINEERING

This is the oldest of all. We have not been able to surpass the works of the past in grandeur or durability. The pyramids of Egypt still stand, and will stand for thousands of years. Roman bridges, aqueducts, and sewers still perform their duties. Joseph's canal still irrigates Lower Egypt. The great wall of China, running for fifteen hundred miles over mountains and plains, contains one hundred and fifty millions of cubic yards of materials and is the greatest of artificial works. No modern building compares in grandeur with St. Peter's, and the mediæval cathedrals shame our puny imitations.

These mighty works were built to show the piety of the Church or to gratify the pride of kings. Time and money were of no account. All this has now been changed. Capital controls, and the question of time, money, and usefulness rules everything. Hence come scientific design and labor-saving machinery.

The engineer of our modern works first calculates the stresses on all their parts, and proportions them accordingly, so that there is no waste of material. Hand labor has given place to steam machinery. All parts are interchangeable, so that they can be made and fitted together in the least possible time, as 423 is seen every day in the construction of a steel-framed office building. Our workmen receive much higher wages than in the past, while time and cost have been diminished.

RAILWAYS

The greatest engineering work of the nineteenth century was the development of the railway system which has changed the face of the world. Beginning in 1829 with the locomotive of George Stephenson, it has extended with such strides that, after seventy years, there are 466,000 miles of railways in the world, of which 190,000 miles are in the United States. Their cost is estimated at forty thousand millions of dollars, of which ten thousand millions belong to the United States.

The rapidity with which railways are built in the United States and Canada contrasts strongly with what has been done in other countries. Much has been written of the energy of Russia in building 3000 miles of Siberian railway in five or six years. In the United States an average of 6147 miles was completed every year during ten successive years, and in 1887 there were built 12,982 miles. The physical difficulties overcome in Siberia are no greater than have been overcome here.

This rapid construction is due to several causes, the most potent of which has been the need of extending railways over great distances with little money. Hence they were built economically, and at first in not as solid a manner as those of Europe. Steeper gradients, sharper curves, and lighter rails were used. This rendered necessary a different kind of rolling-stock suitable to such construction. The swivelling-truck and equalizing-beam enabled our engines to run safely on tracks where the rigid 424
European engines would soon have been in the ditch.

Our cars were made longer, and by the use of longitudinal framing much stronger. A great economy came from the use of annealed cast-iron wheels, with hardened tires, all in one piece, instead of being built up of spokes, hubs, and tires in separate parts. These wheels now seldom break, and cost much less than European wheels. As there are some eleven million car-wheels in use in the United States the resulting economy is great.

It was soon seen that longer cars would carry a greater proportion of paying load, and the more cars that one engine could draw in a train, the less would be the cost. It was not until the invention by Bessemer in 1864 of a steel of quality and cost that made it available for rails that much heavier cars and locomotives could be used. Then came a rapid increase. As soon as Bessemer rails were made in this country, the cost fell from $175 per ton to $50, and now to $26.

Before that time a wooden car weighed sixteen tons, and could carry a paying load of fifteen tons. The thirty-ton engines of those days could not draw on a level over thirty cars weighing 900 tons.

The pressed steel car of to-day weighs no more than the wooden car, but carries a paying load of fifty tons. The heaviest engines have now drawn on a level fifty steel cars, weighing 3750 tons. In the one case the paying load of an engine was 450 tons; now it is 2500 tons.

Steep grades soon developed a better brake system, and these heavier trains have led to the invention of the automatic brake worked from the engine, and also automatic couplers, saving time and many lives. The capacity of our railways has been greatly increased by the use of electric block-signals.

The perfecting of both the railway and its rolling-stock has led to remarkable results.

We have no accurate statistics of the early operation of American railways. In 1867 Poor’s Manual 425
estimated their total freight tonnage at 75,000,000 and the total freight receipts at $400,000,000. This was an average rate per ton of $5.33.

In 1899 Poor gives the total freight tonnage at 975,789,941 tons, and the freight receipts at $922,436,314, or an average rate per ton of ninety-five cents. Had the rates of 1867 prevailed, the additional yearly cost to the public would have been $4,275,000,000, or sufficient to replace the whole railway system in two and a half years.

This is an illustration only, but a very striking one. Everybody knows that such high rates of freight as those of 1867 would have checked traffic. This much can surely be said: the reduction in cost of operating our railways, and the consequent fall in freight rates, have been potent factors in enabling the United States to send abroad last year $1,456,000,000 worth of exports and flood the world with our food and manufactured products.

BRIDGE BUILDING

In early days the building of a bridge was a matter of great ceremony, and it was consecrated to protect it from evil spirits. Its construction was controlled by priests, as the title of the Pope of Rome, "Pontifex Maximus," indicates.

Railways changed all this. Instead of the picturesque stone bridge, whose long line of low arches harmonized with the landscape, there came the straight girder or high truss, ugly indeed, but quickly built, and costing much less.

Bridge construction has made greater progress in the United States than abroad. The heavy trains that we have described called for stronger bridges. The large American rolling-stock is not used in England, and but little on the continent of Europe, as the width of tunnels and other obstacles will not 426 allow of it. It is said that there is an average of one bridge for every three miles of railway in the United States, making 63,000 bridges, most of which have been replaced by new and stronger ones during the last twenty years.

This demand has brought into existence many bridge-building companies, some of whom make the whole bridge, from the ore to the finished product.

Before the advent of railways, highway bridges in America were made of wood, and called trusses. Few of them existed before railways. The large rivers and estuaries were crossed in horse-boats, a trip more dangerous than an Atlantic voyage now is. A few smaller rivers had wooden truss bridges. Although originally invented by Leonardo da Vinci, in the sixteenth century, they were reinvented by American carpenters. Some of Burr's bridges are still standing after more than one hundred years' use. This shows what wood can do when not overstrained and protected from weather and fire.

The coming of railways required a stronger type of bridge to carry concentrated loads, and the Howe truss, with vertical iron rods, was invented, capable of 150-foot spans.

About 1868 iron bridges began to take the place of wooden bridges. Die-forged eyebars and pin connections allowed of longer panels and longer spans. One of the first long-span bridges was a single-track railway bridge of 400-foot span over the Ohio at Cincinnati, which was considered to be a great achievement in 1870.

The Kinzua viaduct, 310 feet high and over half a mile long, belongs to this era. It is the type of the numerous high viaducts now so common.

About 1885 a new material was given to engineers, having greater strength and tenacity than iron, and commercially available from its low cost. This is basic steel. After many experiments, the proper 427 proportions of carbon, phosphorus, sulphur, and manganese were ascertained, and uniformity resulted. The open-hearth process is now generally used. This new chemical metal, for such it is, is fifty per cent. stronger than iron, and can be tied in a knot when cold.

The effect of improved devices and the use of steel is shown by the weights of the 400-foot Ohio River iron bridge, built in 1870, and a bridge at the same place, built in 1886.

The bridge of 1870 was of iron, had panels twelve feet long, and its height was forty-five feet, and span 400 feet.

The bridge of 1886 was of steel, had panels thirty feet long, and its height was eighty feet. Its span was 550 feet. The weights of the two were nearly alike.

The cantilever design, which is a revival of a very ancient type, came into use. The great Forth Bridge, in Scotland, 1600-foot span, is of this style, as are the 500-foot spans at Poughkeepsie, and now a new one is being designed to cross the St. Lawrence near Quebec, of 1800-foot span.

This is probably near the economic limit of cantilever construction, but the suspension bridge can be extended much farther, as it carries no dead weight of compression members.

The Niagara Suspension Bridge, of 810-foot span, built by Roebling, in 1852, and the Brooklyn Bridge, of 1600 feet, built by Roebling and his son, twenty years after, marked a wonderful advance in bridge design.

Thirty years later, when a new bridge of 1600 feet was wanted to cross another part of the East River at New York, the same lines of construction were followed, and they will be followed in the 2700-foot span, designed to cross the North River some time in the present century. The only radical 428
advance is the use of a better steel than could be had in earlier days.

Steel-arched bridges are now scientifically designed. Such are the new Niagara Bridge, of 840-foot span, and the Alexandra Bridge at Paris.

It is curious to see how little is said about these beautiful bridges, which the public takes as a matter of course. If they had been built fifty years ago, their engineers would have received the same praise as Robert Stephenson or Roebling, and justly so, as they would have been men of exceptional genius. When these bridges were built, in 1898, the path had been made so clear by mathematical investigation and the command of a better steel, that the task seemed easy.

That which marks more clearly than anything else the great advance in American bridge building, during the last forty years, is the reconstruction of the famous Victoria Bridge, over the St. Lawrence, above Montreal. This bridge was designed by Robert Stephenson, and the stone piers are a monument to his engineering skill. For forty winters they have resisted the great fields of ice borne by a rapid current. Their dimensions were so liberal that the new bridge was put upon them, although four times as wide as the old one.

The superstructure was originally made of plate-iron tubes, reinforced by tees and angles, similar to Stephenson’s Menai Straits Bridge. There are twenty-two spans of 240 feet each, and a central one of 330 feet. Perhaps these tubes were the best that could be had at the time, but they had outlived their usefulness. Their interiors had become greatly corroded by the confined gases from the engines and the drippings from the chemicals used in cold-storage cars. Their height was insufficient for modern large cars, and the confined smoke made them so dark that the number of trains was greatly limited.

It was decided to build a new bridge of open-work construction and of open-hearth steel. This was 429
done, and the comparison is as follows: Old bridge, sixteen feet wide, single track, live load of one ton per foot; new bridge, sixty-seven feet wide, two railway tracks and two carriage-ways, live load five tons per foot.

The old iron tubes weighed 10,000 tons, cost $2,713,000, and took two seasons to erect. The new truss bridge weighs 22,000 tons, has cost between $1,300,000 and $1,400,000, and the time of construction was one year.

During his experience the writer has seen the rolling-load of bridges increase from 2000 to 4000 pounds per lineal foot of track, with an extra allowance for concentrated loads.

The modern high office building is an interesting example of the evolution of a high-viaduct pier. Such a pier of the required dimensions, strengthened by more columns strong enough to carry many floors, is the skeleton frame. Enclose the sides with brick, stone, or terra-cotta, add windows, and doors, and elevators, and it is complete.

Fortunately for the stability of these high buildings, the effect of wind pressures had been studied in this country in the designs of the Kinzua, Pecos, and other high viaducts.

All this had been thoroughly worked out and known to our engineers before the fall of the Tay Bridge in Scotland. That disastrous event led to very careful experiments on wind pressures by Sir Benjamin Baker, the very eminent engineer of the Forth Bridge. His experiments showed that a wind gauge of 300 square feet area showed a maximum pressure of thirty-five pounds per square foot, while a small one of one foot and a half square area registered gusts of forty-one pounds per square foot.

The modern elevated railway of cities is simply a very long railway viaduct. Some idea may be gained of the life of a modern riveted-iron structure from the experience of the Manhattan Elevated Railway of New York. These roads were built in 1878–79 to carry uniform loads of 1600 pounds per lineal foot, except Second Avenue, which was made to carry 2000. The stresses were below 10,000 pounds per square inch. 430

These viaducts have carried in twenty-two years over 25,000,000 trains, weighing over 3,000,000,000 tons, at a maximum speed of twenty-five miles an hour, and are still in good order.

Bridge engineers of the present day are free from the difficulties which confronted the early designers of iron bridges. The mathematics of bridge design was understood in 1870, but the proportioning of details had to be worked out individually. Every new span was a new problem. Now the engineer tells his draughtsman to design a span of a given length, height, and width, and to carry such a load. By the light of experience he does this at once.

Connections have become standardized so that the duplication of parts can be carried to its fullest extent.

Machine tools are used to make every part of a bridge, and power riveters to fasten them together. Great accuracy can now be had, and the sizes of parts have increased in a remarkable degree.

We have now great bridge companies, which are so completely equipped with appliances for both shop drawings and construction that the old joke becomes almost true that they can make bridges and sell them by the mile.

All improvements of design are now public property. All that the bridge companies do is done in the fierce light of competition. Mistakes mean ruin, and the fittest only survives.

Having such powerful aids, the American bridge engineer of to-day has advantages over his predecessors and over his European brethren, where the American system has not yet been adopted. 431

The American system gives the greatest possible rapidity of erection of the bridge on its piers. A span of 518 feet, weighing 1000 tons, was erected at Cairo on the Mississippi in six days. The parts were not assembled until they were put upon the false works. European engineers have sometimes ordered a bridge to be riveted together complete in the maker’s yard, and then taken apart.

The adoption of American work in such bridges as the Atbara in South Africa, the Gokteik viaduct in Burmah, 320 feet high, and others, was due to low cost, quick delivery and erection, as well as excellence of material and construction.

FOUNDATIONS, ETC.

Bridges must have foundations for their piers. Up to the middle of the nineteenth century engineers knew no better way of making them than by laying bare the bed of the river by a pumped-out cofferdam, or by driving piles into the sand, as Julius Cæsar did. About the middle of the century, M. Triger, a French engineer, conceived the first plan of a pneumatic foundation, which led to the present system of compressing air by pumping it into an inverted box, called a caisson, with air locks on top to enable men and materials to go in and out. After the soft materials were removed, and the caisson sunk by its own weight to the proper depth, it was filled with concrete. The limit of depth is that in which men can work in compressed air without injury, and this is not much over one hundred feet.

The foundations of the Brooklyn and St. Louis bridges were put down in this manner.

In the construction of the Poughkeepsie bridge over the Hudson in 1887–88, it became necessary to go down 135 feet below tide-level before hard bottom was reached. Another process was invented to take the place of compressed air. Timber caissons were built, having double sides, and the spaces between them filled with stone to give weight. Their tops were left open and the American single-bucket dredge was used. This bucket was lowered and lifted by a very long wire rope worked by the engine, and with it the soft material was removed. By moving this bucket to different parts of the caisson its sinking was perfectly controlled, and the caisson finally placed in its exact position, and perfectly vertical. The internal space was then filled with concrete laid under water by the same bucket, and levelled by divers when necessary. 432

While this work was going on, the government of New South Wales, in Australia, called for both designs and tenders for a bridge over an estuary of the sea called Hawkesbury. The conditions were the same as at Poughkeepsie, except that the soft mud reached to a depth of 160 feet below tide-level.

The designs of the engineers of the Poughkeepsie bridge were accepted, and the same method of sinking open caissons (in this case made of iron) was carried out with perfect success.

The erection of this bridge involved another difficult problem. The mud was too soft and deep for piles and staging, and the cantilever system in this site would have increased the cost.

A staging was built on a large pontoon at the shore, and the span erected upon it. The whole was then towed out to the bridge site at high tide. As the tide fell, the pontoon was lowered and the steel girder was placed gently on its piers. The whole operation was completed within six hours. The other five spans were placed in the same manner.

The same system was followed afterwards by the engineer of the Canadian Pacific Railway in placing the spans of a bridge over the St. Lawrence, in a very rapid current. It is now used in replacing old spans by new ones, as it interrupts traffic for the least possible time. 433

The solution of the problems presented at Hawkesbury gave the second introduction of American engineers to bridge building outside of America. The first was in 1786, when an American carpenter or shipwright built a bridge over Charles River at Boston, 1470 feet long by forty-six feet wide. This bridge was of wood supported on piles. His work gained for him such renown that he was called to Ireland and built a similar bridge at Belfast.

Tunnelling by compressed air is a horizontal application of compressed-air foundations. The earth is supported by an iron tube, which is added to in rings, which are pushed forward by hydraulic jacks.

A tunnel is now being made under an arm of the sea between Boston and East Boston, some 1400 feet long and sixty-five feet below tide. The interior lining of iron tubing is not used. The tunnel is built of concrete, reinforced by steel rods. This will effect a considerable economy. Success in modern engineering means doing a thing in the most economical way consistent with safety.

The Saint Clair tunnel, which carries the Grand Trunk Railway of Canada under the outlet of Lake Huron, is a successful example of such work. Had the North River tunnel, at New York, been designed on equally scientific principles, it would probably have been finished, which now seems problematical.

The construction of rapid-transit railways in cities is another branch of engineering, covering structural, mechanical, and electrical engineering. Some of these railways are elevated, and are merely railway viaducts, but the favorite type now is that of subways. There are two kinds, those near the surface, like the District railways of London, the subways in Paris, Berlin, and Boston, and that now building in New York. The South London and Central London, and other London projects, are tubes sunk fifty to eighty feet below the surface and requiring elevators for access. These are made on a plan devised by Greathead, and consist of cast-iron tubes pushed forward by hydraulic rams, and having the space outside of the tube filled with liquid cement pumped into place. 434

The construction of the Boston subway was difficult on account of the small width of the streets, their great traffic, and the necessity of underpinning the foundations of buildings. All of this was successfully done without disturbing the traffic for a single day, and reflects great credit on the engineer. Owing to the great width of New York streets, the problem is simpler in that respect, but requires skill in design and organization to complete the work in a short time. Although many times as long as the Boston subway, it will be built in nearly the same time. The design, where in earth, may be compared to that of a steel office building twenty miles long, laid flat on one of its sides. The reduplication of parts saves time and labor, and is the key to the anticipated rapid progress. Near the surface this subway is built in open excavation, and tunnelling is confined to rock.

The construction of power-houses for developing energy from coal and from falling water requires much structural besides electrical and mechanical engineering ability. The Niagara power-house is intended to develop 100,000 horse-power; that at the Sault Ste. Marie as much; that on the St. Lawrence, at Massena, 70,000 horse-power. These are huge works, requiring tunnels, rock-cut chambers, and masonry and concrete in walls and dams. They cover large extents of territory.

The contrast in size of the coal-using power-houses is interesting. The new power-house now building by the Manhattan Elevated Railway, in New York, develops in the small space of 200 by 400 feet 100,000 horse-power, or as much power as that utilized at Niagara Falls. 435

One of the most useful materials which modern engineers now make use of is concrete, which can be put into confined spaces and laid under water. It costs less than masonry, while as strong. This is the revival of the use of a material used by the Romans. The writer was once allowed to climb a ladder and look at the construction of a dome of the Pantheon, at Rome. He found it a monolithic mass of concrete, and hence without thrust. It is a better piece of engineering construction than the dome of St. Peter’s, built fifteen hundred years later. The dome of Columbia College Library, in New York, is built of concrete.

Concrete is a mixture of broken stone or gravel, sand, and Portland cement. Its virtue depends upon the uniform good quality of the cement. The use of the rotary kiln, which exposes all the contained material to a uniform and constant intense heat, has revolutionized the manufacture of Portland cement. The engineer can now depend upon its uniformity of strength.

Wheels, axles, bridges, and rails have all been strengthened to carry their increased loads; but, strange to say, the splices which hold in place the ends of the rails, and which are really short-span bridges, are now the weakest part of a railway. The angle-bar splice has but one-third of the strength of the rail, and its strength cannot be increased, owing to its want of depth. Joints go down under every passing wheel, and the ends of the rails wear out long before the rest.

This is not an insignificant detail. It has been estimated by the officers of one of the trunk lines that a splice of proper design and strength would save yearly enough in track labor (most of which is 436
expended in tamping up low joints) to buy all the new rails and fastenings required in some time. It would save much more than that in the wear of rolling-stock. A perfect joint would be an economic device next in value to the Bessemer steel rail. Here is a place for scientific and practical skill.

HYDRAULIC ENGINEERING

This is one of the oldest branches of engineering, and was developed before the last century. The irrigation works of Asia, Africa, Spain, Italy, the Roman aqueducts, and the canals of Europe, are examples. Hydraulic works cannot be constructed in ignorance of the laws which govern the flow of water. The action of water is relentless, as ruined canals, obstructed rivers, and washed-out dams testify.

The principal additions of the nineteenth century to hydraulic engineering are the collection of larger statistics of the flow of water in pipes and channels, of rainfall, run-off, and available supply. It is now known that the germs of disease can be retained by ordinary sand filters, and it is now an established fact that pure drinking water and proper drainage are a sure preventive of typhoid and similar fevers. Very foul water can be made potable. Experiments show that the water of the Schuylkill

River at Philadelphia, which contains 400,000 germs in the space of less than a cubic inch, was so much purified by filtering that only sixty remained. This is a discovery of sanitary science, but the application of it is through structural engineering, which designs and executes the filter beds with great economy.

The removal of sewage, after having been done by the Etruscans before the foundation of Rome, became a lost art during the dirty Dark Ages, when filth and piety were deemed to be connected in some mysterious way. It was reserved for good John Wesley to point out that “Cleanliness is next to 437
godliness.” Now sewage works are as common as those for water supply. Some of them have been of great size and cost. Such are the drainage works of London, Paris, Berlin, Boston, Chicago, and New Orleans. A very difficult work was the drainage of the City of Mexico, which is in a valley surrounded by mountains, and elevated only four to five feet above a lake having no outlet. Attempts to drain the lake had been made in vain for six hundred years. It has lately been accomplished by a tunnel six miles long through the mountains, and a canal of over thirty miles, the whole work costing some $20,000,000.

The drainage of Chicago by locks and canal into the Illinois River has cost some $35,000,000, and is well worth its cost.

Scientific research has been applied to the designing of high masonry and concrete dams, and we know now that no well-designed dam on a good foundation should fail. The dams now building across the Nile by order of the British government will create the largest artificial lakes in the world. The water thus stored will be of inestimable value in irrigating the crops of Lower Egypt. Their cost, although great, will not exceed the sums spent by the lavish Khedive Ismail on useless palaces, now falling to decay.

The Suez Canal is one of the largest hydraulic works of the last century, and is a notable instance of the displacement of hand labor by the use of machinery. Ismail began by impressing a large part of the peasant population of Egypt, just as Rameses had done over 3000 years before. These unfortunate people were set to dig the sand with rude hoes, and carry it away in baskets on their heads. They died by thousands for want of water and proper food. At last the French engineers persuaded the Khedive to let them introduce steam dredging machinery. A light railway was laid to supply provisions, and a 438
small ditch dug to bring pure water. The number of men employed fell to one-fourth. Machinery did the rest. But for this the canal would never have been finished.

The Panama Canal now uses the best modern machinery, and the Nicaragua Canal, if built, will apply still better methods, developed on the Chicago drainage canal, where material was handled at a less cost than has ever been done before.

Russia is better supplied with internal waterways than any other country. Her rivers rise near each other, and have long been connected by canals. It is stated that she has over 60,000 miles of internal navigation, and is now preparing the construction of canals to connect the Caspian with the Baltic Sea.

The Erie Canal was one of very small cost, but its influence has been surpassed by none. The “winning of the West” was hastened many years by the construction of this work in the first quarter of the century. Two horses were just able to draw a ton of goods at the speed of two miles an hour over the wretched roads of those days. When the canal was made these two horses could draw a boat carrying 150 tons four miles an hour. Mud, or, in other words, friction, is the great enemy of civilization, and canals were the first things to diminish it, and after that railways.

The Erie Canal was made by engineers, but it had to make its own engineers first, as there were none available in this country at that time. These self-taught men, some of them land surveyors and others lawyers, showed themselves the equals of the Englishmen Brindley and Smeaton, when they located a water route through the wilderness, having a uniform descent from Lake Erie to the Hudson, and which would have been so built if there had been enough money.

The question now is whether to enlarge the capacity of this canal by enlarging its prism and locks, 439
or to increase speed and move more boats in a season by electrical appliances. The last method seems more in line with those of the present day.

There should be a waterway from the Hudson to Lake Erie large enough for vessels able to navigate the lakes and the ocean. A draft of twenty-one feet can be had at a cost estimated at $200,000,000.

The deepening of the Chicago drainage canal to the Mississippi River, and the deepening of the Mississippi itself to the Gulf of Mexico, is a logical sequence of the first project. The Nicaragua Canal would then form one part of a great line of navigation, by which the products of the interior of the continent could reach either the Atlantic or Pacific Ocean.

The cost would be small compared with the resulting benefits, and some day this navigation will be built by the government of the United States.

The deepening of the Southwest Pass of the Mississippi River from six to thirty feet by James B. Eads was a great engineering achievement. It was the first application of the jetty system on a large scale. This is merely confining the flow of a river, and thus increasing its velocity so that it secures a deeper channel for itself.

The improvement of harbors follows closely the increased size of ocean and lake vessels. The approach to New York harbor is now being deepened to forty feet, a thing impossible to be done without the largest application of steam machinery in a suction dredge boat.

The great increase of urban population, due to steam and electric railways, has made works of water supply and drainage necessary everywhere. Some of these are on a very grand scale. An illustration of this is the Croton Aqueduct of New York as it now is, and as it will be hereafter.

This work was thought by its designers to be on a scale large enough to last for all time. It is now 440
less than sixty years old, and the population of New York will soon be too large to be supplied by it.

It is able to supply 250,000,000 to 300,000,000 gallons daily, and its cost, when the Cornell dam and Jerome Park reservoir are finished, will be a little over $92,000,000.

It is now suggested to store water in the Adirondack Mountains, 203 miles away, by dams built at the outlet of ten or twelve lakes. This will equalize the flow of the Hudson River so as to give 3,000,000,000 to 4,000,000,000 gallons daily. It is then proposed to pump 1,000,000,000 gallons daily from the Hudson River at Poughkeepsie, sixty miles away, to a height sufficient to supply the city by gravity through an aqueduct. This water would be filtered at Poughkeepsie, and we now know that all impurities can be removed.

If this scheme is carried out, the total supply will be about 1,300,000,000 gallons daily, or enough for a population of from 12,000,000 to 13,000,000 persons. By putting in more pumps, filter-beds, and conduits, this supply can be increased forty per cent., or to 1,800,000,000 gallons daily. This water would fill every day a lake one mile square by ten feet deep. This is a fair example of the scale of the engineering works of the nineteenth and twentieth centuries.

By the application of modern labor-saving machinery, the cost of this work can be so far controlled that the cost to the city of New York per 1,000,000 gallons would be no greater than that of the present Croton supply.

All works of hydraulic engineers depend on water. But what will happen if the water all dries up? India, China, Spain, Turkey, and Syria have suffered from droughts, caused clearly by the destruction
of their forests. The demand for paper to print books and newspapers upon, and for other purposes, is 441
fast converting our forests into pulp. We cannot even say, “After us the deluge,” for it will seldom rain in those evil days. When the rains do come, the sponge-like vegetation of the forests being gone, the streams will be torrents at one time of the year and dried up during the rest, as we now see in the arid regions of the West.

MECHANICAL ENGINEERING

This is employed in all dynamical engineering. It covers the designs of prime motors of all sorts, steam, gas, and gasoline reciprocating engines; also steam and water turbines, wind-mills, and wave-motors.

It comprises all means of transmitting power, as by shafting, ropes, pneumatic pressure, and compressed air, all of which seem likely to be superseded by electricity.

It covers the construction of machine tools and machinery of all kinds. It enters into all the processes of structural, hydraulic, electrical, and industrial engineering. The special improvements are: The almost universal use of rotary motion, and of the reduplication of parts.

The steam-engine is a machine of reciprocating, converted into rotary, motion by the crank. The progress of mechanical engineering during the nineteenth century is measured by the improvements of the steam-engine, principally in the direction of saving fuel, by the invention of internal combustion or gas-engines, the application of electrical transmission, and, latest, the practical development of steam turbines by Parsons, Westinghouse, Delaval, Curtis, and others. In these a jet of steam impinges upon buckets set upon the circumference of a wheel. It was clearly indicated by the Italian engineer Bronca, in 1629, but he was too early. The time was not ripe, and there were then no machine tools giving the 442
perfection of workmanship required.

Their advantages are that their motion is rotary and not reciprocal. They can develop speed of from 5000 to 30,000 revolutions per minute, while the highest ever attained by a reciprocating engine is not over 1000. Their thermodynamic losses are less, hence they consume less steam and less fuel.

It is a very interesting fact that the basic invention upon which not only steam turbines and electric dynamos, but, indeed, all other parts of mechanical engineering, depend, is of such remote antiquity that we know nothing of its origin. This is the wheel which Gladstone said was the greatest of man's mechanical inventions, as there is nothing in nature to suggest it.

Duplication of parts has lowered the cost of all products. Clothing is one of these. The parts of ready-made garments and shoes are now cut into shape in numbers at a time, by sharp-edged templates, and then fastened together by sewing-machines.

Mechanical engineering is a good example of the survival of the fittest. Millions of dollars are expended on machinery, when suddenly a new discovery or invention casts them all into the scrap heap, to be replaced by those of greater earning capacity.

Prime motors derive their energy either from coal or other combinations of carbon, such as petroleum, or from gravity. This may come from falling water, and the old-fashioned water-wheels of the eighteenth century were superseded in the nineteenth by turbines, first invented in France and since greatly perfected. These are used in the electrical transmission of water-power at Niagara of 5000 horse-power, and form a very important part of the plant.

The other gravity motors are wind-mills and wave-motors. Wind-mills are an old invention, but have been greatly improved in the United States by the use of the self-reefing wheel. The great plains 443
of the West are subject to sudden, violent gales of wind, and unless the wheel was automatically self-reefing it would often be destroyed. Little has been written about these wheels, but their use is very widely extended, and they perform a most useful function in industrial engineering.

There have been vast numbers of patents taken out for wave-motors. One was invented in Chili, South America, which furnished a constant power for four months, and was utilized in sawing planks. The action of waves is more constant on the Pacific coast of America than elsewhere, and some auxiliary power, such as a gasoline engine, which can be quickly started and stopped, must be provided for use during calm days. The prime cost of such a machine need not exceed that of a steam plant, and the cost of operating is much less than that of any fuel-burning engine. The saving of coal is a very important problem. In a wider sense, we may say that the saving of all the great stores which nature has laid up for us during the past, and which have remained almost untouched until the nineteenth century, is *the* great problem of to-day.

Petroleum and natural gas may disappear. The ores of gold, silver, and platinum will not last forever. Trees will grow, and iron ores seem to be practically inexhaustible. Chemistry has added a new metal in aluminum, which replaces copper for many purposes. One of the greatest problems of the twentieth century is to discover some chemical process for treating iron, by which oxidation will not take place.

Coal, next to grain, is the most important of nature's gifts; it can be exhausted, or the cost of mining it become so great that it cannot be obtained in the countries where it is most needed; water, wind, and wave power may take its place to a limited extent, and greater use may be made of the waste 444
gases coming from blast or smelter furnaces, but as nearly all energy comes from coal, its use must be economized, and the greatest economy will come from pulverizing coal and using it in the shape of a fine powder. Inventions have been made trying to deliver this powder into the fire-box as fast as made, for it is as explosive as gunpowder, and as dangerous to store or handle. If this can be done, there will be a saving of coal due to perfect and smokeless combustion, as the admission of air can be entirely regulated, the same blast which throws in the powder furnishing oxygen. Some investigators have estimated that the saving of coal will be as great as twenty per cent. This means 100,000,000 tons of coal annually.

Bituminous coal will then be as smokeless as anthracite, and can be burned in locomotives. Cities will be free from the nuisance of wasted coal, which we call soot. This process will be the best kind of mechanical stoking, and will prevent the necessity of opening the doors of fire-boxes. The boiler-rooms of steamships will no longer be "floating hells," and the firing of large locomotives will become easy.

Another problem of mechanical engineering is to determine whether it will be found more economical to transform the energy of coal, at the mines, into electric current and send it by wire to cities and other places where it is wanted, or to carry the coal by rail and water, as we now do, to such places, and convert it there by the steam or gas engine.

In favor of the first method it can be said that hills of refuse coal now representing locked-up capital can be burned, and the cost of transportation and handling be saved. Electric energy can now transport power in high voltage economically between coal-mines and most large cities.

The second method has the advantage of not depending on one single source of supply, that may 445
break down, but in having the energy stored in coal-pockets near by the place of use, where it can be applied to separate units of power with no fear of failure.

It seems probable that a combination of the two systems will produce the best results. Where power can be sent electrically from the mines for less cost than the coal can be transported, that method will be used.

To prevent stoppage of works, the separate motors and a store of coal, to be used in cases of emergency, will still be needed, just as has been described as necessary to the commercial success of wave-motors.

ELECTRICAL ENGINEERING

Any attempt by the writer of this article to trace the progress of electricity would be but a vain repetition, after the admirable manner in which the subject has been treated in a former paper of this series by Professor Elihu Thomson.

We can only once more emphasize the fact that it is by the union of four separate classes of minds—scientific discoverers, inventors, engineers, and capitalists—that this vast new industry has been created, which gives direct employment to thousands, and, as Bacon said 300 years ago, has "endowed the human race with new powers."

METALLURGY AND MINING

All the processes of metallurgy and mining employ statical, hydraulic, mechanical, and electrical engineering. Coal, without railways and canals, would be of little use, unless electrical engineering came to its aid.

It was estimated by the late Lord Armstrong that of the 450,000,000 to 500,000,000 tons of coal annually produced in the world, one-third is used for steam production, one-third in metallurgical 446 processes, and one-third for domestic consumption. This last item seems large. It is the most important manufacturing industry in the world, as may be seen by comparing the coalless condition of the eighteenth century with the coal-using condition of the nineteenth century.

Next in importance comes the production of iron and steel. Steel, on account of its great cost and brittleness, was only used for tools and special purposes until past the middle of the last century. This has been all changed by the invention of his steel by Bessemer in 1864, and open-hearth steel in the furnace of Siemens, perfected some twenty years since by Gilchrist & Thomas.

The United States have taken the lead in steel manufacture. In 1873 Great Britain made three times as much steel as the United States. Now the United States makes twice as much as Great Britain, or forty per cent. of all the steel made in the world.

Mr. Carnegie has explained the reason why, in epigrammatic phrase: “Three pounds of steel billets can be sold for two cents.”

This stimulates rail and water traffic and other industries, as he tells us one pound of steel requires two pounds of ore, one and one-third pounds of coal, and one-third of a pound of limestone.

It is not surprising, therefore, that the States bordering on the lakes have created a traffic of 25,000,000 tons yearly through the Sault Ste. Marie Canal, while the Suez, which supplies the wants of half the population of the world, has only 7,000,000, or less than the tonnage of the little Harlem River at New York.

INDUSTRIAL ENGINEERING

This leads us to our last topic, for which too little room has been left. Industrial engineering covers statical, hydraulic, mechanical, and electrical engineering, and adds a new branch which we 447 may call chemical engineering. This is pre-eminently a child of the nineteenth century, and is the conversion of one thing into another by a knowledge of their chemical constituents.

When Dalton first applied mathematics to chemistry and made it quantitative, he gave the key which led to the discoveries of Cavendish, Gay-Lussac, Berzelius, Liebig, and others. This new knowledge was not locked up, but at once given to the world, and made use of. Its first application on a large scale was made by Napoleon in encouraging the manufacture of sugar from beets.

The new products were generally made from what were called “waste material.” We now have the manufacture of soda, bleaching powders, aniline dyes, and other products of the distillation of coal, also coal-oil from petroleum (known fifty or sixty years ago only as a horse medicine), acetylene gas, celluloid, rubber goods in all their numerous varieties, high explosives, cement, artificial manures, artificial ice, beet-sugar, and even beer may now be included.

Through many ages, the alchemists, groping in the dark, and in ignorance of nature’s laws, wasted their time in trying to find what they called the philosopher’s stone, which they hoped would transform the baser metals into gold.

If such a thing could be found it would be a curse, as it would take away one of the most useful instruments we have—a fixed standard of value.

In a little over one hundred years, those working by the light of science have found the true philosopher's stone in modern chemistry. The value of only a part of these new products exceeds the nominal value of all the gold in the world.

The value of our mechanical and chemical products is great, but it is surpassed by that of food products. If these did not keep pace with the increase of population, the theories of Malthus would be 448 true—but he never saw a modern reaper.

The steam-plough was invented in England some fifty years since, but the great use of agricultural machinery dates from our Civil War, when so many men were taken from agriculture. It became necessary to fill their places with machinery. Without tracing the steps which have led to it, we may say that the common type is what is called "the binder," and is a machine drawn chiefly by animals, and in some cases by a field locomotive.

It cuts, rakes, and binds sheaves of grain at one operation. Sometimes threshing and winnowing machines are combined with it, and the grain is delivered into bags ready for the market.

Different machines are used for cutting and binding corn, and for mowing and raking hay, but the most important of all is the grain-binder. The extent of their use may be known from the fact that 75,000 tons of twine are used by these machines annually.

It is estimated that there are in the United States 1,500,000 of these machines, but as the harvest is earlier in the South, there are probably not over 1,000,000 in use at one time. As each machine takes the place of sixteen men, this means that 16,000,000 men are released from farming for other pursuits.

The "man with the hoe" has disappeared from the real world, and is only to be found in the dreams of poets.

It is fair to assume that a large part of these 16,000,000 men have gone into manufacturing, the operating of railways, and other pursuits. The use of agricultural machinery, therefore, is one explanation of why the United States produces eight-tenths of the world's cotton and corn, one-quarter of its wheat, one-third of its meat and iron, two-fifths of its steel, and one-third of its coal, and a large 449 part of the world's manufactured goods.

CONCLUSION

It is a very interesting question, why was this great development of material prosperity delayed so late? Why did it wait until the nineteenth century, and then all at once increase with such rapid strides?

It was not until modern times that the reign of law was greatly extended, and men were insured the product of their labors.

Then came the union of scientists, inventors, and engineers.

So long as these three classes worked separately but little was done. There was an antagonism between them. Ancient writers went so far as to say that the invention of the arch and of the potter's wheel were beneath the dignity of a philosopher.

One of the first great men to take a different view was Francis Bacon. Macaulay, in his famous essay, quotes him as saying: "Philosophy is the relief of man's estate, and the endowment of the human race with new powers; increasing their pleasures and mitigating their sufferings." These noble words seem to anticipate the famous definition of civil engineering, embodied by Telford in the charter of the British Institution of Civil Engineers: "Engineering is the art of controlling the great powers of nature for the use and convenience of man."

The seed sown by Bacon was long in producing fruit. Until the laws of nature were better known, there could be no practical application of them. Towards the end of the eighteenth century a great intellectual revival took place. In literature appeared Voltaire, Rousseau, Kant, Hume, and Goethe. In pure science there came Laplace, Cavendish, Lavoisier, Linnæus, Berzelius, Priestley, Count Rumford, James Watt, and Dr. Franklin. The last three were among the earliest to bring about a union of pure and applied science. Franklin immediately applied his discovery that frictional electricity and lightning were the same to the protection of buildings by lightning-rods. Count Rumford (whose experiments on the conversion of power into heat led to the discovery of the conservatism of energy) spent a long life in contriving useful inventions. 450

James Watt, one of the few men who have united in themselves knowledge of abstract science, great inventive faculties, and rare mechanical skill, changed the steam-engine from a worthless rattletrap into the most useful machine ever invented by man. To do this he first discovered the science of thermodynamics, then invented the necessary appliances, and finally constructed them with his own hands. He was a very exceptional man. At the beginning of the nineteenth century there were few engineers who had received any scientific education. Most of them worked by their constructive instincts, like beavers, or from experience only. It took a lifetime to educate such an engineer, and few became eminent until they were old men.

Now there is in the profession a great army of young men, most of them graduates of technical schools, good mathematicians, and well versed in the art of experimenting. The experiments of undergraduates on cements, concrete, the flow of water, the impact of metals, and the steam-engine, have added much to the general stock of knowledge.

One of the present causes of progress is that all discoveries are published at once in technical journals and in the daily press. The publication of descriptive indexes of all scientific and engineering articles as fast as they appear is another modern contrivance.

Formerly scientific discoveries were concealed by cryptograms, printed in a dead language, and hidden in the archives of learned societies. Even so late as 1821 Oersted published his discovery of the uniformity of electricity and magnetism in Latin. 451

Engineering works could have been designed and useful inventions made, but they could not have been carried out without combination. Corporate organization collects the small savings of many into great sums through savings-banks, life insurance companies, etc., and uses this concentrated capital to construct the vast works of our days. This could not continue unless fair dividends were paid. Everything now has to be designed so as to pay. Time, labor, and material must be saved, and he ranks highest who can best do this. Invention has been encouraged by liberal patent laws, which secure to the inventor property in his ideas at a moderate cost.

Combination, organization, and scientific discovery, inventive ability, and engineering skill are now united.

It may be said that we have gathered together all the inventions of the nineteenth century and called them works of engineering. This is not so. Engineering covers much more than invention. It includes all works of sufficient size and intricacy to require men trained in the knowledge of the physical conditions which govern the mechanical application of the laws of nature. First comes scientific discovery, then invention, and lastly engineering. Faraday and Henry discovered the electrical laws which led to the invention of the dynamo, which was perfected by many minds. Engineering built such works as those at Niagara Falls to make it useful.

An ignorant man may invent a safety-pin, but he cannot build the Brooklyn Bridge.

The engineer-in-chief commands an army of experts, as without specialization little can be done. His is the comprehensive design, for which he alone is responsible.

Such is the evolution of engineering, which began as a craft and has ended as a profession. 452

In past times, civilization depended upon military engineering. Warriors at first used only the weapons of the hand. Then came military engineering, applied both to attack and defence, and culminating in the invention of gunpowder. The civilization of to-day depends greatly upon civil engineering, as we have tried to show. It has changed the face of the world and brought all men nearer together. It has improved the condition of man by sanitary appliances and lowering the cost of food. It has shown that through machinery the workman is better educated, and his wages are increased, while the profits of capital increase also. It has made representative government possible over vast areas of territory, and is democratizing the world.

Thoughtful persons have asked, will this new civilization last, or will it go the way of its predecessors? Surely the answer is: all depends on good government, on the stability of law, order, and justice, protecting the rights of all classes. It will continue to grow with the growth of good government, prosper with its prosperity, and perish with its decay.

Thomas C. Clarke.

455

RELIGION

CATHOLICISM

It is no unnatural curiosity that tempts us to recollect ourselves at the end of a century and consider the gains and losses of three generations, our inheritance from the past, our own administration of the same, and the prospects of our descendants. Religion can only gain from such a survey, for she is a world teacher on so large a scale that all ordinary human methods of comparison and summary are too dwarfed and insufficient for her. Her message is to all humanity; hence only the most universal criteria are rightly applicable to her. It seems to me that that is especially true of the oldest historical form of Christianity, which is Roman Catholicism.

The Roman Church has had a message for all humanity in every age ever since Saint Clement penned his famous epistle to the Corinthians, or Saint Victor caused the Christian world to meet in special councils for the solution of a universal difficulty. It is no mere coincidence that, at the opening of the last century of this mystical and wonderful cycle of two thousand years, the Bishop of Rome should again address the world in tones whose moderation and sympathy recall the temper and the arguments of Saint Clement, his far-away predecessor and disciple of Saint Peter.

The year 1800 was a very disheartening one for Catholicism. It still stood erect and hopeful, but in the midst of a political and social wreckage, the result of a century of scepticism and destructive 456 criticism that acted at last as sparks for an ungovernable popular frenzy, during which the old order appeared to pass away forever and a new one was inaugurated with every manifestation of joy. The tree of political liberty was everywhere planted, and the peoples of Europe promised themselves a life of unalloyed comfort for all future time. Catholicism was the religion of the majority of these people, and was cunningly obliged to bear the brunt of all their complaints, justified and unjustifiable; although the authorities of Catholicism had long protested against many of the gravest abuses of the period, sustained in formal defiance of the principles and institutions of the Catholic religion. The new Cæsar threatened to be more terrible to the independence of religion than any ancient one, and the revenues and establishments by which Catholicism had kept up its public standing and earned the esteem and gratitude of the people were swept away or *quasi* ruined.

All the acquired charges and duties of the past were left to the Catholic religion; yet the means to carry them on were taken away, sometimes by open violence, sometimes by insidious measures, but always by gross injustice. The final incidence of this injustice was on the common people, since the Church was, after all, only the administrator of very much that she was thus dispossessed of.

With this overturning of all the conditions of Catholic life came new problems, new trials, and a period of indefinite, uncertain circumstances that were finally set at rest only at the Congress of Vienna in 1815, by which an end was put to the political changes that began with the Revolution of 1789.

The *modus vivendi* then reached, and soon consecrated by a series of concordats, has remained substantially the basis of the dealings of Catholicism with the governments of the Old World. Only one 457 formal and permanent violation of this legal situation has taken place, the violent and unjust dispossession of the Holy See by the government of the House of Savoy, in flagrant violation of every title that could be invoked by a legitimate civil power. Elsewhere Catholicism has undergone much suffering, both in the states of the Old World and in the republics of South America. But, the above vital conflict apart, the old century closed with no very acute or intolerable condition of things, although there is much that does not reply to our ideas of fairness and justice.

THE VATICAN COUNCIL

The chief event of the century, from the point of view of Roman Catholicism, is undoubtedly the holding of the Vatican Council. Since the Council of Trent the bishops of the Catholic world had not met in common under the guidance of the Bishop of Rome. The gravest interests of religion seemed at stake after more than a century of public infidelity and the overthrow of all former safeguards of faith. The character of doctrinal authority and its visible tangible possessor were declared by the dogma of Papal infallibility. The genuine relations of reason and revelation were set forth in unmistakable language.

The troubles that followed the close of the Council in some parts of Europe were neither serious nor long-lived, since its teachings were in keeping with the general sense of Catholicism. It promoted, notably, mutual respect and concord among the bishops and gave to the multitudes of Catholics in the Old and New Worlds a new sign of the unity and internal vigor of the Church. The scenes of the Council are indelibly fixed in my memory, for I was the youngest and humblest of the six hundred and 458
sixty-seven bishops who composed it.

A General Council is the very highest act of the life of the Church, since it presents within a small compass, and at once, all the movements that have been developing in the course of centuries, and offers to all the faithful and to all outside the Church straightforward answers to all the great ecclesiastical problems that come up for settlement. Had the Vatican Council been finished it would have taken up the grave subject of ecclesiastical discipline. That is reserved for the reopening of the Council at some future date.

THE MISSIONS OF CATHOLICISM

It is incumbent on the Catholic Church to spread the teachings of Jesus Christ, and this by His own divine command: “Going, therefore, teach all nations.”

In this last century she has not been unfaithful, any more than in others. No portion of the vineyard has been neglected; the martyr’s blood has watered some parts more abundantly, but in all the missionary has toiled without ceasing, has spent himself. In the Far East Catholic missions have been carried on in India, China, Thibet, Tonkin. In every part of Africa, northern, central, and southern, the priests and nuns of the Catholic Church have preceded the explorer or followed the trader and the miner with the blessings of religion. In the still pagan parts of North and South America her missionaries are found all through the century. They have kept up their vigils in the Holy Land, and in general have made a notable progress.

The inventions of the age have been beneficial by opening up new lands and by making transit easy and rapid, thus recalling some of the conditions which conduced to the original spread of the 459
religion of Jesus. A multitude of noble souls have devoted all to the enlightenment of the barbarian and pagan world. And while I disparage no land, and do not undervalue the good intentions and efforts of those outside our pale, I cannot pass over in silence the French nation, which has given more abundantly than any, perhaps more abundantly than all others, of priests, sisters, and funds for the essential duty of Catholicism. The work of the Propagation of the Faith and the Seminary of Foreign Missions at Paris deserve a special souvenir as often as Catholic missions are mentioned.

THE POPES OF THE CENTURY

Six Popes ruled the Church in the nineteenth century: Pius VII., Leo XII., Pius VIII., Gregory XVI., Pius IX., and the present venerable pontiff, Leo XIII. In the person of Pius VII. they have known what martyrdom was like, also the shame and humiliation of being subject to a civil power absolute in its character and prone to unwarrantable interference with the ecclesiastical power, even to contempt of its most ancient and venerable rights. In Gregory XVI. and Pius IX. they learned the purposes and the power of those who in Europe have succeeded to the men of the French Revolution. In Leo XIII. their line, the oldest line of rulers on the earth, can boast of a most enlightened mind and a very sympathetic heart. Long time a bishop of an important see before he was made Pope, he has been at the level of every task imposed upon the Papacy.

In a particular manner he has been the patron of ecclesiastical studies, by his scholarly encyclicals on philosophy, Scripture, history, and other branches of learning. A noble specimen of this activity is his late letter to the bishops of France on the studies of the clergy. His spirit is the Christian spirit of 460
reconciliation and concord, yet without sacrifice of the immemorial rights and the solemn obligations of the Apostolic See. He may not live to see the restoration of his independence, and the reparation of the wrong inflicted upon the Holy See, but he can maintain a protest that will forever invalidate among Catholics the claim of the actual government and keep open the Roman question until it is rightly settled.

Catholics cannot forget that the Pope for the time being is, according to Catholic doctrine, the successor of Saint Peter in all his rights and privileges as the visible head of the Church, appointed by Jesus Himself. Hence, among other duties, he has to safeguard the approved traditions and the general legislation of the past, to protect the status of the Church as given over to him, and to hand it down undiminished to his own successor. Precisely because he is the head of the Church he may not licitly alter its organic and regular life, or arbitrarily abandon the almost sacrosanct ways along which his predecessors have moved, or give up lightly the institutions in which religion has gradually found a setting for itself.

I venture to say that this element of fixity in the attitude of the Apostolic See will be more appreciated in another age, more constructive and architectonic than the past, less querulous and destructive, even if less daring and brilliant. Forever to pull down and scatter, and never to build up and perfect, cannot be the final purpose of human society. It is perhaps worth remarking that the average reign of the Popes was much longer in the nineteenth century than in any other, being over sixteen years, and that two successive reigns, those of Pius IX. and Leo XIII., represent fifty-four continuous years of Church government at Rome, a phenomenon not witnessed since the foundation of 461
that Church by Saint Peter and Saint Paul.

THE CATHOLIC HIERARCHY

During this century the Holy Father has been able to restore the Catholic hierarchy in England, Scotland, Holland, and to create it anew in India. This means the orderly management of the works and the purposes of the Catholic religion, since the episcopate is the divinely instituted organ for its spread and its administration. In many lands a numerous episcopate has sprung up. In our own beloved country it has grown almost at the rate of one see for every year of the century. The apostolic activity of the episcopate has been usually beyond reproach. The care of souls, the creation of parishes, building of churches, convents, schools, and charitable institutions has gone on in every diocese of the Catholic world. Some bishops have distinguished themselves by their sanctity of life and their love for the poor; others by their learning and their skill in their writing works of utility for the faithful; others by their holy martyrdoms, both in pagan and Christian lands; others by devotion to great works of common charity and utility—nearly all by their exemplary lives and the conscientious performance of their duties.

No nation has a monopoly of this outpouring of the highest sacerdotal devotion; and no nation or people, as far as I can learn, has been without a steady succession of remarkable bishops, men who would have done honor to any age of Christian history. I believe that it is the constant and edifying service of the episcopal body which is chiefly responsible for the improvement in learning, morality, and laborious enlightened zeal on the part of the clergy, diocesan and monastic, which it seems just to claim for the nineteenth century. In some lands the episcopal office is freer than in others, and its 462 beneficent activity is more immediate and visible. In all the bishops have kept the bond of unity, often at no inconsiderable sacrifice of personal comfort. Neither schism nor heresy of any formal and noteworthy nature has been connected with the episcopal office. It would ill become me to discriminate where the merits are so equal. I may, however, be permitted to rejoice with my countrymen at the end of the century that the life and the teachings of a Carroll, a Cheverus, a Bruté a Neumann, a Dubois, have not been without salutary effect, and have set a shining mark for the imitation of all coming generations. Particularly have such men inculcated habitual courtesy and charity in dealing with all those who did not share the faith of Catholics. They were fresh from the storms of foreign religious hatred and infidel intolerance, and knew by personal experience the benefit of mutual good understanding and personal respect.

In the United States, particularly, the Catholic episcopate has been very active in providing for the most fundamental spiritual needs of their flocks—churches for religious services, priests for the administration of sacraments, schools for the preservation of the revealed Christian faith, orphanages for the little waifs and castaways of society. Whether short or long, the periods of government of these Church rulers have never been idle nor marked by self-indulgence. Almost every one has left some monument of faith as a contribution to the general good of Catholicism. I would neither exaggerate nor boast, yet it occurs to me, after many years of service, travel, and observation, that few ages of Christianity can show a more laborious and elevated episcopate than the nineteenth century.

The recruiting of the diocesan clergy has been the gravest duty of this episcopate, for religion lives by and for men. It can get along without wealth or monuments, but not without intelligent teachers of 463 its tenets and faithful observers of its precepts. In keeping with the decrees of the Council of Trent diocesan seminaries have been opened where it was possible, and elsewhere provincial institutions of a similar character. Both flourish in the United States, and grow more numerous with every decade. The older clergy, long drawn from the venerable schools of Europe, have left a sweet odor among us, the purest odor of self-sacrificing lives, of devotion to poor and scattered flocks, of patient, uncomplaining contentment with the circumstances of poverty and humility. There is no diocese in the United States where there cannot be heard tales of the hardships and brave lives of the ecclesiastics who laid the foundations of religion. We remember them always, and hold their names in benediction. The younger generation of our clergy enjoys advantages denied to their predecessors; but we consider that they owe it to those predecessors if they have a degree of leisure to perfect the culture of their minds, and a faithful Catholic people to ask for the benefits which must accrue from greater learning, if it be solid and well directed.

Yet I cannot admit that our older clergy were deficient in the learning of the schools. The names of England and Corcoran are at once on our lips, not to speak of a long array of others almost equally entitled to distinguished mention. If the external conditions of the diocesan clergy have improved, their relations to the Church authority have been safeguarded with even greater earnestness and efficiency. The dispositions of synods, provincial councils, and the three plenary councils of Baltimore have, we are happy to say, had little to do with questions of doctrine. They have all been held for the improvement of discipline and notably for the welfare of the clergy. In the same direction, also, have tended the numerous decisions and instructions from the Roman congregations, whose wisdom has 464 never been invoked by us in vain, and whose sympathy for our conditions we gratefully acknowledge.

THE CONGREGATION OF THE PROPAGANDA

Any account of the good influence of the Holy See on our ecclesiastical conditions would be unjust and incomplete if the Congregation of the Propaganda Fide were omitted. To it we owe an unceasing surveillance, full of prudence and intelligence. From its offices have come to the bishops regularly counsel, warning, encouragement, co-operation. It has been eminently just and fair, also fearless in the application of the principles, the spirit, and the letter of canonical discipline. Its action is a calm and grave one, marked by reticence and patience and that composure which belongs to the highest judicial decisions. But the Catholic Church in the United States and in Canada owes it an undisputed debt of gratitude. The most learned cardinals of the century and the best ecclesiastical talent have co-operated in the creation of its legislation, which need not fear the criticism of any learned and honest judicial body of men.

RELIGIOUS ORDERS AND COMMUNITIES

In the religious orders and communities the Catholic Church possesses a very ancient auxiliary force that has rendered incalculable help during the century. By their numbers, their strong inherited traditions, their central government, their willing obedience, and their other resources they have come everywhere to the aid of the bishops and the diocesan clergy. Often they bore alone and for a long time, and at great sacrifices, the whole burden of religion. Their praise is rightly on all sides, and their 465 works speak for them, when their modesty and humility forbid them to praise themselves. The missions of Catholicism in this century, as in others, have largely fallen to them. They stood in the breach for the cause of education when the churches were too poor and few to open colleges. They have given countless missions and retreats, and in general have not spared themselves when called upon for works of general utility. They and their works are of the essence of Catholicism, and they ought rightly to flourish in any land where they are free to live according to the precepts and the spirit of their founders, who are often canonized saints of the Catholic Church.

I shall not be saying too much when I assert that among the invaluable services rendered to the Church by Catholic women of all conditions of life—no unique thing in the history of Catholicism—those rendered by the women of religious communities are of the first rank of merit. Primary Catholic education, in the United States, at least, would have been almost impossible without their devotion. It is owing to them that the orphans have been collected and cared for, the sick housed and sheltered, the poor and helpless and aged, the crippled and the blind, looked after regularly and lovingly. They surely walk in the footsteps of Jesus, doing good wherever they go. The perennial note of sanctity in the Catholic Church shines especially in them. Content with food and clothing and shelter, they devote their lives, often in the very flower of youth and health and beauty, to the weak and needful members of Christian society. He must needs be a Divine Master who can so steadily charm into His service the purest and the most affectionate of hearts, and cause them to put aside deliberately for love of Him even the most justifiable of human attachments. This argument for Christianity is not new; it was 466 urged by Saint Justin the Martyr on the libertine world of the Antonines.

THE UNITY OF CHRISTENDOM

Throughout this century the Roman Church has desired and sought by all practical means the restoration of the former unity of Christendom. Each succeeding Pope has appealed to the ancient but separated Churches of the Orient, reminding them of the past oneness and the need of union with that see which all their records proclaim the rock and centre of unity. Similarly, appeals have been issued to the divided Christian communities of the West, as when Pius IX. wrote to the members of the Protestant world before the Vatican Council, and when Leo XIII. lately addressed his famous encyclical on the Unity of the Church to all men of good will within the Anglican pale. Such efforts may seem perfunctory; but they have in our eyes a deep meaning. They proclaim the doctrine of unity that is clearer than the noonday sun from the teachings of Jesus; they make a first step in the direction of its restoration; they keep alive the spirit of charity in many hearts, and they stir up countless prayers for the consummation of an end that few believing Christians any longer consider unnecessary. Already the canker-worms of doubt and indifference are gnawing at those last foundations of the old inherited Christian religious beliefs that still worked beneficently outside the pale of Catholic unity, but are now disappearing from the public consciousness because, too often, they are no longer elements of private conviction. In the realm of faith, as in that of nature, there is an after-glow, when the central sun has spent its force; but in both that glow is the herald of coldness and darkness. To those who no longer allow in their hearts any Christian belief, Catholicism has strongly appealed in the 467 nineteenth century by its teachings on the right use of reason in matters of faith, the claims of religion on the mind and the heart of man, the benefits of Christianity, and its superiority over all other forms of religion—in a word, by the constant exposé of all the motives of credibility which could affect a sane and right mind that had divested itself of prejudice and passion.

CONVERSIONS TO CATHOLICISM

Not the least remarkable share of the history of Catholicism is seen in the stream of conversions that began in the very stress of the French Revolution and has not ceased to flow since then. From every land of the Old and New Worlds hundreds of thousands have returned of their own volition to the ancient fold wherein we firmly believe is kept the sacred deposit of saving truth. They have come to us from the pulpits of opposing religions and from the workshops of an unbelieving science. Every condition of life, and both sexes, have sent us numerous souls. Very many of these conversions have been unsolicited and unexpected. Some of them meant an accession of wealth or social prestige or high rank. Others brought with them the beloved tribute of uncommon intelligence, experience of life and men, acquired erudition, the highest gifts of style and oratory. Very many have come from the middle walks of life, and signified no more than a great weariness of pursuing shadows for the reality of divine truth, and the excessive goodness of the Holy Spirit of God which bloweth where it listeth. Of this army of converts some have been drawn by the conviction that the Bible alone, without an interpreter and a witness divinely guaranteed, could not suffice as a rule of faith. Others have been moved by the incarnation in the Church of the spirit and functions of authority without which no 468 society can exist. Still others have come back to the Mother of all churches, through a deep heart-weariness at the endless dilapidation of divine truth outside the Roman Church. Some have sought and found through the study of history the open door to the truth. Others again through the study of art and its functions in the Christian Church. In whatever way they returned to the unity of the original sheepfold, they are an eloquent witness to the innate vigor and the immortal charm of the Christian truth as preserved in Catholicism. For they have come in unconditionally. Their return has worked beneficially, not only for themselves, but for those of the Catholic faith, whom it has consoled and encouraged for their steadfastness, while the non-Catholic world cannot but feel that that religion is worthy of respect, even of study, which can forever draw so many men and women out of the ranks of its adversaries, even at the sacrifice of many things which are usually held dear by society.

THE RELATIONS WITH CIVIL AUTHORITY

Being a genuine and world-wide religion, Catholicism could not but come into contact with the powers in which rests the social authority.

In many cases the fundamental relations of both have been settled by documents of a *quasi* constitutional character known as concordats. They are binding on both parties, yet in more than one case the supreme authority of Catholicism has had reason to complain of their violation either in letter or in spirit.

Important points like the freedom of episcopal elections, the management of ecclesiastical revenues, the freedom of access to and communication with the Holy See, have been tampered with or openly abolished. In a general way Catholics are far from being content with the actual administration 469
of these *quasi* treaties between the civil and the ecclesiastical powers in the Old World and in South America—yet they respect them and desire to live up to their requirements. It is to be hoped that in the new century there will be less suspicion of the truly beneficent intentions of the Church, and less hampering of the common organs of her existence and work. In a century filled with revolutions as no other the Catholic Church has comported herself with dignity and equity, and managed to find the correct *via media* in this great tangle of opposing and mutually destructive forms and theories of government.

THE CATHOLIC CHURCH AND THE UNITED STATES

In our own beloved country we have every reason to be thankful that the liberty to worship God according to the dictates of conscience is guaranteed by the Constitution, and has entered deeply into the convictions of our fellow-citizens. The Catholic Church, by her own constitution, is deeply sympathetic with our national life and all that it stands for. She has thrived in the atmosphere of liberty, and seeks only the protection of the common law, that equal justice which is dealt out to all. She is the oldest historical and continuous government on the earth, and it is no small index of the value of our institutions and their durability that they make provision for the life and the work of so vast and so aged a society. It would also seem to show that, through a long course of centuries, Catholicism held as its own genuine political teachings only such as were finally compatible with the most perfect and universal citizenship known to history.

When this nation was forming, the first Catholic bishop in the United States, and my first
predecessor in the see of Baltimore, John Carroll, accepted and performed satisfactorily the gravest 470
public duty of a citizen, an embassy to another people for the benefit of his own country. Thereby he left to us all an example and a teaching that we shall ever cherish, the example of self-sacrifice as the prime duty of every citizen, and the teaching that patriotism is a holy conviction to which no Catholic, priest or layman, can hold himself foreign or apathetic.

A Catholic layman of the same distinguished family, Charles Carroll of Carrollton, threw in his lot with the patriots from the beginning, and by word and deed served the cause of American liberty, while he lived to see it flourish and inform more and more the minds and hearts of the first generation of American citizens. In future centuries, as in this, his name will be held in honor and benediction as a signer of the Declaration of Independence. His Catholic belief and conduct will forever be a potent encouragement to the children of his own faith. He was the first layman to contribute notably to the cause of Catholic education, and the native formation of the priesthood, by the establishment of a college for that purpose.

THE CATHOLIC CHURCH AND EDUCATION

We have done our best in these ten decades to provide the best education for our people and our priests. Intimately convinced that general education without religion is destined to be an evil rather than a blessing, we have created all over the United States a system of primary education in parochial schools that has cost us and yet costs us the gravest sacrifices and entails the heaviest solicitudes. Yet we feel that we are serving the cause of God and country by indoctrinating our Catholic youth with
persuasions of the existence of God and His holy attributes, of the true nature of vice and virtue, of 471
conscience and sin, of the spiritual and the temporal, of the proper purposes of life, of punishment and reward in an immortal life. We believe that Christianity is better than paganism; also that Christianity is something simple, positive, historical, that can and ought to be taught from the cradle to the grave,

good for all conditions, for both sexes, and for every situation in life this side of the common grave. Believing this, we have shaped our conduct accordingly, and trust to God for the issue. In such matters it imports more to be right in principle than to be successful. Our secondary system of education has gone on from the founding of the Republic. Colleges for boys and academies for girls have risen up in every State and Territory, have been supported by the faithful people, and are doing an incalculable good. As our means increase and other advantages offer, we hope to improve them; Catholicism is no stagnant pool, but a field for every good private initiative that respects right and truth. In the Catholic University of America, founded in the last decade of the century by Pope Leo XIII. and the Catholic hierarchy, after due and lengthy deliberation, and made possible by the magnificent generosity of a Catholic woman, we have centred our hopes of a system of higher education that shall embody the best traditions of our ancient Church and the approved gains of our own times. American Catholics have not disposed in the past of great wealth, inherited or earned; hence all these works mean an incredible devotion and intensity of good will and sustained sacrifices. Wherever the Catholic Church has been strong and successful, schools of every kind flourish. I need only recall the fact that the idea, the constitution, the functions, the influences of a university were unknown in the world until she created the type in the Middle Ages, and gave over to mankind a new factor in civil and religious life 472 —the power of organized learning.

THE SOCIAL MOVEMENT

Through the whole century one line of thought and action has been gradually disengaging itself from all others and dominating them. That is the social movement, or the tendency towards a more evenly just and natural conception of all the relations that arise from the common dwelling of mankind in organized society. It has long taken the form of institutions and plans for the betterment of the conditions of the people, of woman, of all who suffer or think they suffer from the actual organization of society. If there is something Utopian in certain plans or hopes, there is too much that is justifiable at the root of other attempts to reorganize our social conditions. Not to speak of the undesirable inheritances of the past, the new conditions created for the common man by the spread of industrialism and commercialism have often been painful in the extreme, and have aroused both violent protests and deep sympathy. By the help of God we have abolished the reproach of slavery in every civilized land, but we hear from the laboring multitudes a vague cry that they are already in the throes of a return to that accursed institution.

Here the doctrines of Catholicism are eminently in accord with the right conception of human nature, the functions of authority and mutual help or charity, the duty to live, and the right to all the necessary means for that end. She is sympathetic, historically and naturally, to the toiling masses, who, after all, form everywhere the bulk of her adherents, and have been always the most docile and affectionate of her members. It is she who created in the world the practical working idea of a common humanity, the basis of all genuine social improvement. The trials of Catholicism have come more often 473 from the luxury and the sin of those in high places than from the disaffection of its great masses. As this movement has gathered force, and passed from theories into the domain of action, the Catholic Church, through her head, has followed it with attention and respect. The whole pontificate of Leo XIII. is remarkable for acts and documents which have passed into the history of social endeavor in the nineteenth century. His personal charities, large and enlightened, are as nothing in comparison with the far-reaching acts like the refusal to condemn the association of the Knights of Labor. His encyclical on the Condition of Workingmen recalls the only possible lines of a final concord between labor and capital—the spirit and teachings of Jesus Christ, the best Friend our common humanity ever had. In the same way, his latest encyclical on Jesus Christ, with which the religious history of the century closes, emphasizes the true basis for the restoration of peace and harmony and justice between the poor and the rich, between the producers of capital and the capital that stimulates and regulates production. We may be confident that the papacy of the future will not show less enlightenment and sympathy in its attempts to solve these delicate and grave problems with the least injustice and the greatest charity.

LIGHTS AND SHADOWS

It would be idle to deny or to palliate the many shadows that fall across the history of Catholicism in the century that has elapsed. I scarcely need refer to the weaknesses and errors of her individual children: such acts she repudiates, and when she can chastises remedially. But the Church has not recovered that vast inherited moral power over the public life which it enjoyed before the French Revolution. In many ways the consequences of atheism, materialism, and even of deism, have been 474
deduced into manners and institutions, to the detriment of the ancient Christian morality. The sterner Christian virtue of previous centuries, founded on the Christian revelation, has been forced out of the public life of whole peoples. Expediency, opportunism, moral cowardice have often triumphed over the plain right and the fair truth. The principle has been established that God is on the side of the great battalions, is ever with the strong men of blood and iron. Ancient and venerable sovereignties have been hypocritically dispossessed. Small nationalities have been erased from the world's political map, and the history of the near past almost justifies the rumors of impending steps in the same direction. With the increase of greatness in states comes an increase of warlike perils, not only from commercial rivalry, but from that root of ambition and domination which grows in every heart, unless checked and subdued in time, and which in the past has been too often the source of violent injustice on the greatest scale.

These deeds and principles we believe to be a necessary result of naturalism, of the exclusion of the supernatural and revealed elements of Christianity from our public life, and not only these, but others of a graver character, that must one day follow from their logical and unchecked evolution. Divorce, a cause of ruin in every land, grows with rapidity in many civilized nations, so much so that not only Catholicism, its inveterate enemy, is shocked, but Christian men of every persuasion believe that some public and authoritative steps ought to be taken to prevent the pollution of the family life, that fixed and natural source of public morality. Religion has been officially thrust out of the systems of education, in every grade, and the young mind taught that it is quite a private and unimportant thing. Thus, under the plea of indifference, many States have practically made themselves the champions of that agnosticism which is the arch-enemy not only of religion, but also of patriotism from time 475
immemorial connected with religion. The average man soon ceases to make great sacrifices, above all to die for the public good, when he is satisfied that there is no other life, or that it is not worth while living for the uncertainties of approval and reward by an eternal God, who is just and true and holy.

REASONS FOR ENCOURAGEMENT

On the other hand, the Catholic man or woman knows that there are great spiritual forces at work in the world, however unhappily its public life may be developing from the view-point of Christian morality. There are innumerable lives guided by the principles of Christian virtue, some of them even culminating in the highest sanctity. Though not all such are known to men, yet not a few become public examples and incitements to virtue. Even outside of the Catholic faith there are not a few who regulate their lives by the natural virtues and also by inherited Christian virtues that work sometimes unconsciously, but whose practice can only be pleasing to our common Father. Sweet Charity is yet a queen in Christian lands; her services and utility are too great to permit her dethronement. Great misfortunes of any kind still touch the hearts of men that are Christian yet when their minds have become clouded by indifference to, or dislike of, the supernatural verities. Luxury and wealth, greater perhaps than the world has yet seen, are still conscious of duties to the common weal. Educational institutions of every character and philanthropical enterprises of every variety have flourished on the means thus provided. But from our point of view it is better that all such phenomena, to be lasting, should have their root and origin in Christian purposes and belief. It is yet true, as it was of old on the hill-sides of Judæa: "Except the Lord build the house, they labor in vain that build it. Except the Lord 476
keepeth the city, he watcheth in vain that keepeth it." (Psalm 126.)

THE FUTURE OF CATHOLICISM

We entertain no doubt that the organization which has weathered the storms and stress of so many centuries will continue to do so in the future. The Catholic Church has the promises of her Divine Founder that the gates of hell shall not prevail against her. How could she doubt of her future? It does not seem likely that any vicissitudes can arise which have not their counterpart or analogy in the past, so old is she on this earth, and so many are the forms of government and the kinds of human culture with which she has lived. We are confident that she will be equal to all the emergencies of the future, for while the Church is always identical with and present to herself in a conscious way, her children and her agents may grow in experience and wisdom, as they undoubtedly do, and may bring both of these factors to bear upon the future problems of our common humanity. Of one thing we may feel certain: she will never cease to desire and to work for that efficacious unity of all Christendom, which is the permanent wish of its Holy Founder, and for which her bishops and priests have never ceased to pray in those opening words of the Roman Canon of the Mass that we repeat daily: "Therefore, O Most Clement Father, we suppliantly pray to Thee through Jesus Christ Our Lord... especially for Thy Holy Catholic Church, which mayst Thou vouchsafe to pacify, keep, unite, and govern throughout the world."

James, Card. Gibbons.

477

PROTESTANTISM

The motives which have acted upon religion in the nineteenth century, either by way of directly enhancing its power or by restricting its influence, are these: (1) Humanitarianism; (2) The Historical Spirit; (3) Science; (4) Nationalism. Although the course of religious history has varied somewhat in different countries as well as in the different Churches, yet it is possible to form an approximate picture of the resultant of these forces which will reveal the progress of the Kingdom of God in the world.

I

The first of these motives—humanitarianism—has powerfully influenced the Christian world by asserting the rights of man, liberty, equality and the spirit of fraternity, the sense of human brotherhood. The germs of the humanitarian movement may be traced in the eighteenth century, as in the teaching of Lessing and Herder and Rousseau; in religious movements like the Great Awakening in the United States, the revival in England under Wesley and Whitefield, in tentative efforts for the abolition of slavery (Hopkins and Clarkson), and prison reform (John Howard). But the nineteenth century has been distinguished above all the other Christian centuries in the results achieved by the sentiment of humanity. It has led to the abolition of slavery under English rule, in the United States, and in Russia; to many reform movements of every kind and degree, wherever there existed actual or 478 latent tyranny, which robbed humanity of its inherent privileges.

The humanitarian sentiment is Christian in its origin, derived primarily from the conviction of the incarnation of God in Christ. Christ appears in history as the leader of humanity in the struggle for freedom. Slowly but surely ever since His advent, the world of man has been moving forward to the attainment of the ideal of humanity revealed in Him. “Ye shall know the truth and the truth shall make you free. And if the Son of God shall make you free, ye shall be free indeed.” The progress towards freedom inspired by Him who taught the fatherhood of God and the brotherhood of men has been accomplished in the face of great hinderances and long reverses, overcoming obstacles which would have been insuperable without Christian faith. In the nineteenth century the movement towards human freedom seems almost to have reached its culmination. Within the sphere of religion the progress is most manifest in the spread of Christian missions, which stand out in any review of the century as one of its most extraordinary achievements. It might be justly designated as a missionary age. So intense and persistent has been its devotion to the gospel of Christ as essential for man that when the century closed it might be truly said that the round world had been girdled with Christian missions, whose results are more significant for civilization, as well as for religion, than any statistics can reveal. The missionary has been the pioneer, it is becoming increasingly evident, of momentous changes yet to appear.

The sentiment of humanity has operated as a motive in the study of human history, giving to historical inquiry a new interest and impetus. No age has been so fruitful in the results of historical research, with conclusions of vital importance for every department of life, but chiefly this, that an independent place has been vindicated for humanity, as having a life of its own distinct from and 479 above the natural order of the physical world. The study of man as he appears in history has tended to strengthen faith in the essential truths of religion, opening up as it has done the deeper knowledge of the nature of man to which the religion of Christ appeals; for the modern method of studying history, as compared with earlier methods, consists in seeking for those inward subjective moods of the human soul which lie beneath creeds or institutions, and not solely in the accurate description of the objective fact. The facts of human life call for interpretation, and for this the historian must search. Thus has been born what is almost a new department of inquiry—the philosophy of history (Hegel and many others). Differ as do these attempts at a philosophy of history, they yet possess one ruling idea—the conviction of a development in the life of humanity when viewed as a whole. The idea of development controlled the higher intellectual life of the first half of the century. It was applied with important results to the study of ecclesiastical history, by Schleiermacher, Neander, Gieseler, Baur, Rothe, Bunsen, and many others, by the Roman Catholic Möhler, in his *Symbolik*, and by John Henry Newman, in however one-sided and imperfect manner. The doctrine of development found its classic formula in the lines of Tennyson:

> “Yet, I doubt not through the ages
> One increasing purpose runs,
> And the thoughts of men are widened
> With the process of the suns.”

The influence of the doctrine of development has been felt in the study of Scripture, leading to a recognition of progressiveness in the divine revelation, whose record has been preserved in the Old
and New Testaments (Mozley, *Ruling Ideas in the Early Ages*). By means of this truth have been 480
overcome, till they now seem unworthy, the objections to the Old Testament on the ground that it gave sanction to cruelty, deceit, or an imperfect morality. But the inference has also followed that the revelation of God to humanity must be searched for in the sacred records, and even by the light of close critical scrutiny, if the divine utterance is to be distinguished from crude misapprehensions or misapplications. Forms of literary expression, current usages, the historical environment of the time—for these allowance must be made as their influence is recognized. The science of biblical criticism has gained from the study of general history a larger knowledge of the nature of man, which, in turn, has made the study of the Bible more profound and thorough, because more real and human than were the biblical studies of the eighteenth century. The primary question which it has been found necessary to ask in regard to any doctrine or institution is not whether it is true—for the canons of truth may vary with the relative position of the inquirer; but, rather, what does it mean? When the meaning of the record is seen, the question of its truth has answered itself.

The effect of these studies, even of what is called the “higher criticism,” has not lessened the authority of the Bible or changed the character of Christianity as “a religion of the book”; but their tendency has been to vindicate the unique and essential place of the Bible in literature as containing the veritable record of a divine revelation. Some things, indeed, have been changed: the order in which the books of the Bible were written is not the order in which they stand; some of them are of composite authorship, whose various parts were written at different times; the traditional chronology, known as Ussher’s (1656), has been abandoned, nor is there anything in the Bible which places it in
opposition to the teachings of geology relative to the length of time during which man has occupied 481
the earth; the historical order of priest and prophet has been reversed, so that the voice of prophecy comes before the decline into ritual (Wellhausen and others). Popular misapprehensions tend to vanish in the light of a true insight and interpretation, such as that the first chapter of Genesis was intended to be an infallible record of the divine order in the creation of the world. That a similar account of the creation is found in Babylonian literature only shows that the Bible writer was illustrating by the best scientific knowledge of the time the vastly higher spiritual truth with which the Bible opens, that the creation is the work of God, thus leading man to the worship of God and away from the lower worships of sun and moon and all the hosts of Heaven.

The mechanical conceptions as to the mode of inspiration and revelation tend to give way before a larger and truer conception of the process by which the revelation is made—that God speaks to man actually and authoritatively through the experience of the events of life. Thus revelation becomes a living process, and all later history may become a commentary on sacred history, renewing and confirming the primal utterance of God to the soul of man. Much, it is true, yet remains to be done in bridging the gulf between the learned and scientific interpretation of the sacred record and the popular apprehension, which, formed in the uncritical moments of youth, often persists to mature years and constitutes a source of confusion and weakness. A similar situation was seen in the Middle Ages in the wide breach which existed between the scholastic theologians and the popular mind.

A new department has been added to religious inquiry in Comparative Religion, which aims at an impartial investigation and free from prejudice, and is also moved by the sentiment of a common 482
humanity to respect all utterances of religious feeling in the soul of man. How widely the nineteenth century has advanced in this respect is seen by recalling a statement of Dr. Johnson: "There are two objects of curiosity—the Christian world and the Mohammedan world. All the rest may be considered as barbarous." One of the most representative monuments of religious scholarship in the last century is Professor Max Müller's *Sacred Books of the East*. Some inquirers in this unfamiliar department have worked under the impression that these ancient religions were equal in value to the Christian revelation; others even have thought them to be in some respects superior. And, in general, the first effect of the discovery that there was truth in other religions had a tendency to weaken the claim of Christianity to be the absolute religion. But as the results of the study have been placed in their normal perspective, it becomes evident that they only confirm the words of St. Paul, that God has at no time left Himself without witnesses in the world. Revelation also is seen to have been a universal process; and profound spiritual motives are to be discerned beneath the diverse manifestations of the religious instincts. Yet, on the whole, the preponderating judgment leads to the conclusion that Christianity contains the larger, even the absolute, truth; that while it confirms some features in these religions as true, it condemns others as false; that Christianity also has for one of its essential characteristics an assimilative power, which not only enables, but forces, it to appropriate as its own any aspects of truth contained in other religions, which have not hitherto been illustrated in the history of the Christian Church. Nor is the familiar test applied to religions wholly indefensible which judges them by their historical fruits or associations. In accordance with this test, Confucianism is represented by China, Hinduism by India, Buddhism by Ceylon and Siam, Mohammedanism by Turkey, Christianity by 483
Europe and America.

The influence of the humanitarian sentiment may be further traced in softening the asperities of some forms of traditional theology, as, for example, the Calvinistic doctrine of election with its alternatives of reprobation or preterition. These certainly have not been the favorite doctrines which have commended themselves to the spirit of the age. The effort has been made to bring the doctrine of the atonement within the limits of human experience. It has been found impossible to present the doctrine of endless punishment after the manner of an earlier age. Many causes have combined to deepen the sense of mystery in which is enveloped the destiny of man, and there has been begotten in consequence an unwillingness to dogmatize where in earlier times such a reluctance was not felt. In this connection may be mentioned two religious bodies, which took their rise about the beginning of the century—Universalism, proclaiming ultimate salvation for all men; and Unitarianism, asserting the dignity of man and his divine endowment. But in all the Churches alike has the same humanizing force been felt, leading to efforts in theological reconstruction in order to make it apparent that the primary truths of Christianity are not merely arbitrary principles or arrangements unrelated to life and to the needs of the soul, but that in their essential quality there is conformity with the larger reason of humanity, with that feeling for the inherent worth of things out of which reason proceeds, and with which its conclusions must conform.

II

Thus far the humanitarian sentiment has been regarded in its combination with Christian faith, and as giving new force and distinction to Christian life and thought. But, on the other hand, it must now 484
be noted that the same force working apart from the Church, and often in opposition to it, has been a limitation to Christian progress. In the French Revolution humanitarianism was associated with a negative, destructive tendency, which overthrew the Church, disowned God and immortality, and set up in the place of deity a so-called Goddess of Reason. This negative tendency has continued to exist and has found influential manifestation. It has attempted the deification of humanity, as though the

human race were worthy in itself of being an object of worship. It has exalted man at the expense of God, conceiving of humanity as alone immortal, as competent to steer its own course without supernatural direction. It has weakened the sense of nationality, has injured and endangered family life, has taken away the highest sanctions from morality, and has reduced religion from being a revelation from God to a purely subjective process in the soul of man, worthy of respect, but without authority. It has created an abnormal sensitiveness in many directions. It has swayed socialistic movements aiming at the rights of man and seeking to achieve universal happiness, but with an antagonism sometimes latent, sometimes expressed, to God and Christ and the Christian Church. The prejudice remains which had its birth in the French Revolution, that religion is a creation of priests for their own selfish ends, and the Church an agency for robbing humanity of its rights, liberty, equality, and fraternity.

Principles and convictions like these found utterance in the philosophy of Comte (1789–1857), who called himself the "founder of the religion of humanity," and who proposed the scheme of a humanitarian Church, limited by no national boundaries, whose only deity was man, whose ritual found a place only for great men who had been the benefactors of the race. Theology and metaphysics 485 were discarded as outgrown methods of explaining the phenomena of the universe, and in the place they vacated stood the so-called "Positive philosophy" which rejected all supernatural influence. The Church of humanity had, indeed, no history and was a failure from its birth. But the combination, first seen in Comte, of humanitarianism with the methods and principles of natural science, has been the most formidable opponent against which Christianity was ever called to struggle. It has been represented in England by John Stuart Mill and by Herbert Spencer and many others. To the influential writings of this school of thinkers is due in great measure the widespread, deep-seated scepticism since the middle of the century. To the same cause, by way of reaction, are owing the spiritualistic movement, the so-called "Christian Science" and other kindred tendencies towards a crude supernaturalism.

Those who entered the controversy in behalf of Christianity and against the adherents of the Positive philosophy suffered at first for the lack of any adequate philosophical method on which to rest in the effort to overcome this stupendous alliance between a humanitarianism working for the improvement of social conditions in combination with natural science, whose postulates involved the denial of the miracle, and indeed of all supernatural agency (agnosticism). It seemed for a time as though the philosophy of Hegel would serve the purpose of a stronghold to which Christian warriors might resort while in the stress of a conflict which involved not only the readjustment of Christian doctrines to their new environment, but also the maintenance of the idea of God, of the kingdom of God in this world and of a future life for the immortal soul. In Germany systems of theology were worked out on the basis of Hegelian principles, which, as interpreted by orthodox theologians, stood 486 for a principle of surpassing value if it could be maintained—that the life of humanity, while dependent in the present order on physical conditions, was yet above the life in external nature with which the natural sciences deal; that the very definition of humanity implies the power of rising to the knowledge of God. Nature has no knowledge or consciousness of God, or intimation of immortality. It is in bondage to natural law and without freedom. The life of humanity must not be studied from the point of view of natural science, but is seen in the records of human history. The influence of Hegel deepened the interest in historical inquiry at a moment when the absorption in the natural sciences threatened to gain the ascendency. But the Hegelian philosophy, for reasons which it is not possible here to render, failed to accomplish the service expected from it. It may be that the failure was temporary only, and because it was not fully understood. There arose a school of thinkers—the Hegelian left wing—who, while retaining their interest in history, yet fell under the influence of the presuppositions of the natural sciences. Thus Strauss, in his *Leben Jesu*, conceived of the person of Christ as a casual product of the human imagination, while Feuerbach, in his *Essence of Christianity*, reached the conclusion that religion begins and ends in a subjective process in the soul. Thus, instead of overcoming the Positive philosophy, German thought gravitated to the same result, with this difference perhaps, that it assumed the form of pantheism rather than of atheism. In the Tübingen school, led by F. C. Baur, whose contributions to the study of Church history are yet of high value, there was reserve about the miracle, if not its tacit denial, and a conception of the Christian Church as a product of human origin rather than the purpose of Christ.

But the effect of Strauss was beneficial in that it sent inquirers back to the study of the person of 487 Christ and of His age. Never before was attention so concentrated upon the life of Jesus, as illustrated in a large number of biographical works, too large to be enumerated here. As a result of these studies, the conviction grows that while there is a local aspect of the person of Christ, so that He reflected the peculiar opinions and living interests of His age, and availed Himself of current beliefs, yet He was also infinitely above His time. What He was and did and said in Palestine nineteen hundred years ago must be supplemented by what He has been to the world in subsequent ages, or what He is and is doing in the present age.

While Christian thinkers were struggling with the problems raised by the Positive philosophy, the natural sciences were commanding in an increasing degree the world's attention, until Darwin made his great discovery of a law of evolution, when it seemed as though natural science had become the arbiter and final tribunal before whose judgments the world must bow. Then there followed the sharp, even bitter conflict between science and theology, when scientific men whose lives had been spent in devotion to the study of natural phenomena were tempted to write expositions of religious history in order to show the fallaciousness of the religious attitude, and theologians, accustomed only to the postulates of the spiritual sphere, ventured into the domain of science to put a spiritual interpretation on its conclusions and discoveries. It was a confusing and painful moment when a subtle scepticism pervaded the Churches and haunted even the minds of Christian believers. Now that the smoke of the battle has cleared away, while many tragedies are disclosed, it does not appear that the Churches have been weakened by the strife or have yielded any essential truth or conviction. The belief in God, and in his creation and government of the world, the incarnation of God in Christ, the miracle for which 488 Christ stands, and pre-eminently the miracle of His resurrection—in a word, the supernatural interpretation of life, remains unshaken. It is unjust to charge, as has sometimes been done, dishonesty and a spirit of evasion against those who, while the fierce battle was in progress, kept silence, unable to defend by cogent argument what yet they cherished still as true.

In the latter part of the century there came efforts at the reconstruction of theology in order to a better adjustment of the increase of knowledge regarding the nature of God and His relation to the world. The doctrine of God as immanent in the world, and not only transcendent or above and apart from it, has proved valuable in reconciling many of the discoveries of history and of natural science with the Christian faith. Efforts have also been made to simplify theology by the reduction of the large and complex, even conflicting, mass of Christian tenets and beliefs, given in history or represented in various Christian sects, to a few simple principles in which all must agree, resting for their confirmation not on metaphysics, but on the genuine Christian instincts as revealed in the New Testament. There has been attained also a better philosophical method for meeting the difficulties and perplexities of the age.

But these attempts at the better interpretation of revealed religion, and the formation of more consistent theological systems, have found a temporary rival in efforts to create, first of all, a better system of "natural theology," as it may be called, which shall take account of the doctrine of evolution and other discoveries of natural science since Paley's time and the day of the Bridgewater Treatises. Those who aim at a reconciliation of religion with science treat the idea of evolution as a mediating principle by which the conflict between science and religion may be overcome. This effort is the more 489 significant, in view of the popular interest in evolution—a word which has become almost the watchword of the age. From this point of view the invasion of religious territory by scientific men (Huxley, Tyndale, Haeckel, and others), and the counter-invasion of scientific territory by philosophers and theologians, give promise of some mutual understanding in the future.

III

It remains now to turn to another most potent motive which has affected the fortunes of religion in the nineteenth century. It may be called Nationalism, meaning by the term that higher conception of the life of the state or nation, slowly but most effectively asserting itself throughout the nineteenth century, never apart from religious convictions, always indeed in their support and furtherance. In illustration of this point, we turn again to the French Revolution, as giving the momentum, both directly and by way of reaction, to the conception of the sacredness of the state, as an ultimate fact in God's government of the world. In that fearful outburst of the French people, their long pent-up indignation was vented no less against the state than against the Church—the one a device of kings and lawgivers for holding mankind in subjection, as the other was a scheme for the same end by a designing priesthood. The humanitarian sentiment received in consequence at this impressive moment a direction of antipathy to nationality as an evil to be overcome, or at least to be kept in subjection to some higher principle, if the rights of man were to be secured. Something even of this negative mood entered into the formation of the American Constitution, where there is to be noted a singular omission of any reference to Deity as the author and preserver of the national life. On the continent of Europe there was the phenomenon of Napoleon building on the ruins of the French Revolution, while yet 490
preserving the destructive motives which inspired it. Napoleon revived the dream of empire, in whose expansive embrace the nations of Europe were to be subordinated, if not suppressed altogether. He proposed to reconstruct the map of Europe, as though nationalities and crowns were purely human artificial arrangements to be disposed of at his sovereign pleasure.

The failure of the French nation, its demonstrated inability to do the proper work of a state, as well as the fact that the career of a Napoleon was possible, indicates inherent weakness in all the nations of Europe at the beginning of the nineteenth century. They existed either in repose, and even stagnation, after the long turmoil of the age of the Protestant Reformation, averse to change, distrustful of enthusiasm, or were content to strive for purely selfish aims. In accordance with the principle that the people existed for the state, rulers followed their personal whims, indifferent to moral sanctions, heedless of the growing evils calling aloud for redress. Such in particular was the condition in France. It was better in England, but even there the same tendency existed, manifested in the unnecessary alienation of the American colonies. However this may be, there has been a reaction against nationality during the nineteenth century. The nations have been forced to struggle against this opposition, and through the struggle they have attained their rebirth, their purification.

The subject is connected with the fortunes of religion in many ways. The indifference to nationality, the distrust of the nation as incompetent for the exigencies of life, the placing of an abstract humanity as an ideal above nationality, so that to labor directly for the interests of humanity apart from the well-being of the nation, and even in its defiance, became the motive of reformers —these characteristics, when seen in the religious sphere, have led to a reaction against the various 491
forms of Protestantism, and especially as represented in the state Churches. The Roman Catholic Church, which in all its history has subordinated national distinctions to the higher interests of a common Christendom, had fallen into inefficiency in the eighteenth century, and was no longer reckoned a force worthy of consideration, either by religious thinkers or by statesmen. But in the first third of the nineteenth century there came a change, when the Roman Church arose from its lethargy to meet the demand imposed upon it by the timid fears of statesmen and ecclesiastics, as the safeguard of religion and morality, where national Churches or particular Churches were thought to have failed. The Napoleonic aspiration after universal empire and the frantic effort to realize it by rearranging or suppressing nationalities has its counterpart in the religious world in the effort to restore a Christian empire with the Papacy at its head, as in the Middle Ages. The effect of this ambition may be seen in Germany and other countries, but is most clearly manifest in England, where the Oxford Movement (1833) appears as an unnational, if not anti-national, uprising in behalf of some imperfectly conceived cosmopolitan Church designated as "Catholicity." The date of the "Movement," as Newman fixed it, was Keble's sermon on the "Apostacy of the National Church." This same feeling, that national existence is inferior in importance to humanitarian reforms or to the expression of religion in some other shape than in any particular or national Church, has been shown in the break with the Established Church in Scotland, or in the difficulties experienced in Germany in consolidating the forms of Protestantism in a strong state Church, or in the aspirations after some universal form of

religion to be accomplished by a parliament of religions. Beneath these various schemes there is the common principle that humanity is a worthier object of devotion than the state, and constitutes a higher ideal in whose cause to labor. This conviction, it may be added, has been strengthened vastly by the extraordinary way in which, during the nineteenth century, the whole world has been brought together by the material forces of steam and electricity. 492

That there is here a great truth no one can deny, but the point to be noticed now is that nationality has been at a disadvantage in the competition with humanity. Out of the necessities of the situation there has been born the spirit of a deeper inquiry into the place and significance of the nation as the indispensable medium by which the highest result can be secured for the world at large. Thus we have the studies in this direction of German students, Hegel and Stahl, Trendelenburg and Bluntschli, Maurice in England, and in America Mulford in his book *The Nation*, all of them combating the motive of Comte and setting forth the essential, even the eternal, significance of nationality. The ancient doctrine is still preserved that the people exist for the state, but it is justified on the ground that the state also exists for the people, for the freedom of the individual man, so that through the state the rights of man are better subserved and more securely guaranteed than by an exclusive one-sided devotion to the cause of an abstract humanity.

As the nineteenth century drew to its close, it became increasingly apparent that the nations had emerged from the depression in which they were found when the century opened. America may be said to have attained the consciousness of nationality in its highest form in consequence of the Civil War, and to have entered from that time upon a new career. In that awful conflict, whose origin dates back to the rise of the anti-slavery movement, may be discerned the issue of the century —humanitarianism, on the one hand, contending for the rights of man, careless, if need be, for the 493 national unity if only a great reform could be secured; and on the other hand, the nation, slowly realizing that slavery was a force hostile to national unity and integrity, and on this ground demanding its suppression. The two attitudes in this instance appear organically related, while yet they spring from distinct and separate motives. In 1870 Germany and Italy took their places in the family of nations. Nor should there be omission to mention Greece, which, after its subsidence for hundreds of years, again attained its national independence.

It has become further apparent that it is to the Protestant nations, America, England, and Germany, that the leading place must be conceded, together with the determination of the world's fortunes. And to these must be added Russia, which is also outside the pale of Latin Christianity. Those nations remaining in alliance with the Papacy are, for the present at least, in an inferior position.

The triumphant assertion of the spiritual significance of nationality in the latter part of the nineteenth century has made it further apparent that the forces working for religion, and especially for its Protestant forms, were stronger than the forces in opposition. The nation enters the arena of the controversy as a spiritual force, assuming as a first principle the existence of God and His supernatural government of the world. Never was this truth more impressively illustrated than in the experience of Lincoln, who, when he became President of the United States in the supreme crisis of its history, ceased to be indifferent to religion and passed into a devout belief in the mysterious control of the destiny of the nation by a sovereign, omnipotent hand. As the indifference to nationality was among the causes of religious doubt and of the weakness in the Churches in the middle of the century, so the 494 triumphant assertion of nationality has contributed to turn the tide towards theistic belief and the Christian faith.

To give a full exposition of the inner relationship of the nation to religion and the Churches is not possible here, but some remarks may be offered which will tend to illustrate their organic connection.

(1) In any large historical survey the nation appears as guided by religious leaders. Religion is seen to have flourished in proportion as the nation is conscious of its strength and destiny. When the Roman Empire broke down the nationalities and merged them in a large composite unity, it broke down also religious faiths, and its own religion as well, till scepticism was the result and a consequent immorality. All attempts to build up religion on the basis of empire, as distinct from nationality, ended in failure.

(2) The Christian religion tended from the first to break up the empire and to restore nationality. Ultimately it became manifest that the cause which undermined the Roman Empire and accomplished its downfall was the Christian Church. In its Eastern half the empire was resolved into nationalities. In the West a Church, Latin Christendom, rose upon its ruins, but within this Latin Christendom the spirit of nationality began at once to work, forcing its way against the opposition of the Papacy, till, in the age of the Protestant Reformation, when nationality was felt as a conscious motive, it sundered Latin Christendom into fragments.

(3) The Old Testament in its form as a whole is simply the history of a nation from its birth through all its fortunes. Never did religion rise to a diviner and fuller expression than under the realization of the conviction that God was protecting the nation and determining its career. The Hebrew prophets were primarily statesmen, devoted to the nationality, as the incarnation of the divine 495 will, in whose fortunes were revealed the divine purpose. Any nation which has not the similar conviction that it is the chosen people of God, and called to some important task, cannot maintain its independence and integrity, and has no future. This conviction to-day inspires the leading nations of the world.

(4) The nation mediates between humanitarianism and individualism. In serving its own ends and seeking to accomplish its mission, it works for the good of all, and also for the freedom of the individual man. The tendency of humanitarianism as a motive apart from the higher life of the state, or apart from its impersonation in Christ as its head and leader, is to weaken individualism and to defeat the very end it wishes to subserve, the achievement of the rights of man. Humanity as a whole lacks the visible, tangible embodiment of the nation. It has not yet the consciousness of itself nor of its unity. It cannot respond to the needs it awakens. It does not, as a whole, realize its relationship to God, nor is it placed in such a position as to make it feel the need of God. It is in danger of becoming an abstraction in so far as it exists without relationships. But the nation is close at hand, near, and felt as a moral personality or being, seeking ideal ends which are also within the bounds of possibility. Humanity as a whole undertakes no enterprises which make it tremble as it comes to unknown, trackless seas. But when the nation comes to great crises, where human wisdom is powerless to direct its course, it falls back instinctively and by necessity upon the belief in the guidance of God. Thus the nation as a whole appears in a higher form of personality than individual men can achieve, even the greatest men, and so prepares the way for the belief in the still higher, the invisible, infinite personality of God.

(5) The nation as a moral personality and depending upon God becomes the safeguard of morals. 496 If there has been a decline in morality in the nineteenth century, as some maintain, shown in the general weakening of moral sanctions, or by the increase of divorce and indifference to the sacredness of family life, it must be attributed in some measure to the indifference to nationality from the time that political liberalism resting on an abstract humanitarianism, or in combination with a scientific naturalism, gained the ascendency. So far as this tendency has in any degree invaded the Christian Church it has been powerless to effect a change for the better. The great men whom humanity is directed to worship do not constitute a moral standard, nor can scientific postulates be made a basis for moral culture; for nature is at least unmoral, if not, as some assert, immoral, and it is only as acted upon by man that nature gives response to the increasing purpose of the world. Religious truths—the personality of God, His creation and government of the world, immortality, and the freedom of the will—these are shattered, we are told, “by the great eternal iron laws of the universe,” or “are in hopeless contradiction with the most solid truths of empirical science.” And so, it must be added, are the sanctions of ethics and moral law. It is when we turn to the state, to the moral personality of the nation, that we encounter other laws and living forces which restore what an empirical science or a transcendental humanitarianism has broken down. Here the supreme test is spiritual—the well-being of the nationality. The state must build upon the family as its corner-stone; it must enforce those moral laws which the history of nations, as well as human experience in its best estate, reveal to be the inmost expression of the normal life of man.

The beginning of a new century may seem like an artificial division of time, but the self-consciousness with which the nineteenth century closed, the efforts at introversive estimates of its 497 place in history and of the work it had accomplished, indicate something more than a conventional barrier to be passed. Prophecies in regard to the new age may be futile, for God reserves to Himself the knowledge of the future. But it is much if we can to any extent read the meaning of the past and detect the sources of its strength and weakness. And for the rest, Christian faith and hope are inextinguishable, looking forward to the fulfilment of the Christian ideal—that higher unity where Christ appears as the embodiment of humanity and the voice of its yearning for a perfect brotherhood; where the nation also acknowledges Him as its overlord, so that, in the words of Christian prophecy, the kingdoms of this world shall become the kingdom of our God and of His Christ. In that ideal conception, the *dominium* belongs to the state, and the *ministerium* to the Christian Church.

Alexander V. G. Allen.

498

THE JEWS AND JUDAISM

The opening years of the nineteenth century found the Jew blinded by the light of a new sun, the rays of which were beating upon the Ghetto and were forcing him to take off, one by one, the many garments with which he had clothed himself during the hostile Middle Ages. For the Jew these Middle Ages did not end with the Reformation and the Renaissance; but only disappeared in the transformation brought about gradually by the French Revolution. The beginning of the twentieth century sees him putting on some of these garments again, and trying to save his own warmth from being lost in the coldness of the outside world. During this period the Jew has passed through more upheavals than many nations have during three or four times the number of years. What outward struggles has he not been called upon to experience; through what alternating seasons of joy and sorrow has he not passed! What changes even within his own body has he not sustained! The modern European and American world has had a hard fight to find its way into its present changed condition; but much harder by far was the task laid upon the Jew; and, whether he has succeeded or not, he has made an honest fight. Evidences of the struggle abound on every hand, and the road is strewn with many a dead hope and many a lost opportunity. The Jew was bound more firmly to ancient traditions; and so interwoven were these ancient traditions with his whole being that the new life into which he came had of necessity to be blended with the old. The tale of the Jew of the nineteenth century is a 499
record of his endeavor to do justice to the two demands which were made upon him: the one from the outside world—to fit himself to take his place worthily and do his work side by side with the other citizens of the state in which he lived; the other from within his own ranks—to harmonize his religious belief with his new point of view and to adapt his religious exercises to modern social conditions.

EMANCIPATION OF THE JEWS

The struggle of the Jews in the various European countries for civil rights and for equality before the law was long drawn out, and was marked by varying fortunes dependent upon the political conditions of these countries. More than seventy years of the century had passed before this struggle had been fought out. Though it is true that a beginning was made in Germany and Austria (1750 and 1781), to France belongs the honor of having been the first to really do away with the mass of anti-Jewish legislation which the centuries preceding had piled up. On the 27th of September, 1791, the National Assembly at one stroke removed all the disabilities under which the Jews had been living—distinctive dress, special Jew's oath, Jew's tax, forced residence in certain localities, etc. From France, and under the influence which that country then exercised, the emancipation of the Jews spread to Belgium and Holland, and to some of the states of Germany; but the rest of Europe was not yet ready for this emancipation. The reaction which marks the period between 1814 and 1848 made itself felt upon the Jews, restoring, in many places, the disabilities under which they had formerly lived. The "Judengassen" became once more inhabited, and the principles of freedom and liberty for all members 500
of the state seemed to have been wellnigh forgotten. The Revolution of 1830 stayed the downward course in some of the German states; but it was not until 1848 that the second great period in Jewish emancipation came about. In the breaking down of old institutions it was natural that the exceptional laws against the Jews should go also. The German Parliament of 1848, at Frankfort, forcefully proclaimed the doctrine of religious liberty; and of this parliament a Jew, Gabriel Riesser, was vice-president. But it was not until the formation of the German Empire, in 1871, that the emancipation of the Jews, which had gradually made its way in the various states, was carried through for the whole of that empire. In 1867, a decree was issued in Austria by virtue of which all citizens were declared equal before the law, and in 1870 the walls of the Ghetto fell in Rome. In 1874, Jews were admitted to the

rank of citizens in Switzerland. In 1878, the Congress of Berlin, the leading spirit of which (Disraeli) was of the Jewish race, demanded equal rights for the Jews living in the Balkan Peninsula. These rights were accorded by the various states there, with the exception of Roumania; which, in spite of the treaty and in spite of the promises made at the time, still continues to refuse to allow the Jews living within its borders to become citizens or to treat them as an integral part of the population. In Turkey the laws which put certain restrictions upon non-Mohammedan citizens were sensibly changed in 1839; so that the Jews living in the dominions of the Sultan suffer from no exceptional legislation.

The cause of Jewish emancipation in England suffered no such sudden changes as it did on the continent. It proceeded by regular stages through the abrogation of the Act of Test in 1828, the admission of Jews as citizens of London in 1830, as sheriffs in 1835, as magistrates in 1845, and in 501
1858 as members of Parliament by the removal of the words "upon the faith of a Christian" in the oath taken by the members. There can be no doubt that the emancipation in England, though long drawn out and fiercely contested, was more effective than anywhere else, owing to the fact that it was progressive in character and based upon the idea of rights demanded and not upon that of favors granted. Nothing was asked of the Jews in England other than that they be good citizens of the state; while the whole continental legislation regarding them, from the time of Napoleon on, had on the part of the legislators only one object in view—to break up the cohesion of the Jews as a body and to pave the way for their disappearance as a distinctive group. The idea that emancipation was a favor and not a right brought it about that the Jews themselves aided in their own disintegration. They believed that it was their duty to show themselves more patriotic than were the other citizens of the state in which they lived, as they were receiving greater favors. And so, even though Jews have sat in the parliaments of various continental states, they have with few exceptions steadfastly refused to acknowledge themselves to be in any way representatives of their brethren, and in some cases (notably in France) during the last few years have either remained supinely indifferent when Jewish questions were before their several parliaments, or have even aided those whose agitation was directed against their fellow-Jews. In England, on the contrary, the Jewish members of Parliament have never forgotten that, in addition to their interests as citizens of England, they have a duty to perform to the Jews, whom they also represent, and they have therefore been able, while giving their best services to the state, to be also useful to their co-religionists. It may be due to this cause that the emancipation of Jews on the continent has in no way been able to stem the recrudescence of anti-Semitism; while it has 502
undoubtedly done this in England. The opposite effect is most clearly seen in Algiers, where the wholesale emancipation of the Jews in 1870, through the efforts of Crémieux, that bold champion of his people, has in a large measure contributed to make the riots possible which have in late years been witnessed in that French colony. Neither the population of Algeria nor the Jews there were at that time ready for such a measure; it did not therefore come as the result of a development among the people, but as something imposed upon them by the government.

In addition to Roumania, Russia is practically the only country which has refused to enter the European concert, and which by means of laws and ordinances represents still the dark period of the Middle Ages. It has turned the provinces on its western borders into a tremendous Ghetto, and driven the Jews to exile by making life within that pale practically impossible. Even Portugal in 1821, and Spain in 1868 (the two countries from which the Jews had been banished for a great number of years), opened their doors to them once more; though few Jews have ventured to return to the Peninsula, despite the fact that in 1886 a committee was formed in Madrid for the promotion of Jewish immigration into Spain.

THE WANDERING JEW

The Wandering Jew is not the Jew of legend, but the Jewish people of history. The dislocation of large Jewish bodies, which was characteristic of the Middle Ages, has been kept up during the nineteenth century; and this dislocation has, as in former times, profoundly modified Judaism in the various countries. From the fifteenth century on to the nineteenth, hostile legislation on the part of 503

Western Europe had been continually driving the Jews to the East. The expulsion from Spain and Portugal, at the end of the fifteenth century, forced several hundred thousand into Turkey; while the hardships which they had to suffer in the smaller German states and in Austria caused large numbers to seek a refuge in Poland and Russia. The tide commenced to turn westward about the middle of the eighteenth century, though bands of Jews from Poland had been driven into Germany, Italy, and Holland in the terrible years of the Chmelnicki persecutions (1648–1651). The readmission of Jews into England, the relative kindness of Frederick William of Prussia and of Frederick the Great, aided a certain slow but continuous infiltration from Poland, so that at the end of the eighteenth or the first half of the nineteenth century these Polish Jews were to be found in all parts of Germany, Holland, and England. This slow migration back again to Western Europe took on, however, much larger proportions in the latter part of the nineteenth century; but before this could happen a strong movement still farther westward had already taken place. Jews were among the earliest settlers on the American continent. They were in nearly every case of Spanish or Portuguese descent, having come from Holland and England to the possessions which these powers held on the new continent. In the middle of the nineteenth century, when the tide of immigration from Germany was at its height, a large number of Jews from the southern states and the Rhine region found their way to these shores. The Russian atrocities of 1882 and the following years caused a greater shifting of the Jewish population westward than can be paralleled at any previous time. It has been estimated that between the years 1882 and 1900 fully one million Russian Jews left their homes in the pale of settlement, finding new 504 dwelling-places in England, Germany, and France. The largest number (probably half a million) came to the United States and Canada. Untoward economic conditions existing in Galicia, and the frequent outbreaks of anti-Semitism there, forced out during the 90’s a large number of Galician Jews; and in 1899 and 1900 the hostility of the Roumanian government has made it impossible for thousands of Jews to remain in a country in which most of them had been born; and, under circumstances the like of which has hardly ever before been seen, bands of the Roumanian Jews have been wandering over Europe, seeking the means by which to come to the American continent in order there to establish themselves anew. There are between ten and eleven million Jews to-day in the world: of these, about nine million live in Europe; one million in the United States and Canada; three hundred and fifty thousand in Africa; three hundred and fifty thousand in Asia; and sixteen thousand in Australasia.

COMMUNAL ORGANIZATION

All these changed circumstances variously modified the organization of the Jewish communities. Napoleon’s attempt in 1807, as the result of the Sanhedrin which he had convened in Paris, to found this organization upon a modern basis, dividing the Jews of France into certain consistories and arrondissements, had an effect not only upon France, but also upon those countries which for a time were under his influence (Holland, Belgium, etc.), and even upon many of the German states. In 1808 such consistories were established in Westphalia and Cassel; in 1809, an Oberrath was created in Baden; and in 1828 and 1831 an Oberkirchenbehoerde in Würtemberg. It was due also to Napoleon that in France and Germany the Jews were obliged to adopt family names, they having, in most cases, 505 still retained the Oriental custom of simply adding to their own prænomen that of their father. Prussia was the only one of the German states which was not so affected. There the state exercises a supervisory influence, compelling all the Jews to be members of the Jewish community, but in no way further regulating the communal life. When the Reform tendencies commenced to make themselves felt in the larger Jewish communities, the Orthodox members safeguarded their own interests by making use of the law passed in 1873, mainly through the efforts of the Jew Lasker, which enabled the people to declare themselves “confessionslos” and form their own synagogues, thus nearing in a measure the system followed in English-speaking countries. In England and America no such organization was effected, as the state does not there take cognizance of the religious belief of the people. In both these countries attempts have been made by the Jews themselves to organize under one head upon a purely religious basis, but without much success. In France there is a Chief Rabbi of the Jews who is recognized by the state as their rabbi and head. But the Chief Rabbi of the Jews in the

British Empire, though he is nominally the head of the Jews in the kingdom, has no actual position as such, and is even not recognized by certain schools of Jews themselves. The Sefardim, or descendants of Spanish and Portuguese Jews, have always kept themselves distinct, and have their own Chief Rabbi, or Haham. In the year 1840, the more liberal-minded element among the London Jews cut themselves loose from the United Synagogue and formed a Reform party, their example being followed in Manchester and Bradford. Neither they nor the recent immigrants from Russia, who have formed their own "Federation of Synagogues" recognize the authority of the Chief Rabbi. This more 506
congregational system has been carried to its utmost limits in the United States, where each congregation is a law unto itself and absolutely rejects any interference on the part of any larger body. From time to time a desire has been manifested to supersede this purely congregational system by some form of union. The late Dr. Isaac M. Wise, of Cincinnati, had at various times attempted to bring the Jews of the United States together with an authoritative synod at their head. Out of this and other attempts have come the Central Conference of American Rabbis and The Union of American Congregations (founded in 1873), which now comprises about ninety-one congregations. These organizations, however, do not by any means represent either all of the Jewish ministers or all of the Jewish congregations, and the Union itself is merely a deliberative body having no power to do anything in the internal affairs of one of its constituent synagogues. Since the union of American Jewish congregations comprises only such as stand upon a Reform platform, a union of Orthodox congregations was formed in New York two or three years ago, and it is hoped that this organization will do much towards binding together the very many congregations of those who adhere strictly to traditional Judaism.

But the organization of Jews as a church has not been found sufficient. Spread over so large a portion of the earth and coming under such varying influences, it was inevitable that the theological differences which already existed should grow apace, and a great cleavage be made between the Orthodox and the Reform wing of the synagogue. It was early felt that some more secular bond must be found which should unite the Jews of various persuasions for common and concerted action. The first attempt in this direction was nobly made by Narcisse Leven, Eugene Emanuel, Charles Netter, 507
and a few others, in founding (1880) the "Alliance Israélite Universelle" in Paris, whose object it was to aid in removing Jewish disabilities wherever they might exist, and to raise the spiritual condition of their coreligionists in Northern Africa, Eastern Europe, and Western Asia by the founding of schools. From these small beginnings the Alliance has grown to be an important factor in the conservation of Jewish interests. Faithful to its programme, it has established a large number of elementary and technical schools, and has intervened actively in Algeria, Morocco, the Turkish Empire, and Persia whenever Jews or Jewish interests were in any way threatened. Its attempt, however, to represent the whole Jewish people has not been successful; for the reason that it has been allied too closely with French national interests; and side by side with the "Alliance Française" it has been an active propagandist of the French language and of French culture in the East. This one-sidedness of its work is best seen in the fact that by its side similar organizations have been created in other countries, "The Board of Delegates of American Israelites" in the United States, "The Anglo-Jewish Association" in England, "The Israeli-tisch Alliance" in Austria, and the "Deutsche Gemeindebund" in Germany. At one time it was hoped that the B'nai B'rith, established in this country in 1843, by Isidor Busch, Julius Bien, and others, would form such a union of Jews, where the theological differences would be eliminated. But though this order, which has 315 lodges in, the United States and Canada, has established itself in such countries as Germany, Roumania, Austria, Algeria, Bulgaria, and Egypt, and despite the good work it has so far done, the mere fact that it is a secret organization prevents it from standing forth as the representative of international Jewry. Where, then, and in what manner is such a 508
body to be found?

ECONOMIC CONDITIONS

The economic condition of the Jews in the large Eastern European Ghettos is, naturally, extremely bad. Huddled together, either in certain districts of large towns or in villages where they form the greater part of the population, they are compelled to live off and on each other. Crowded into certain walks of life by anti-Jewish legislation or anti-Jewish sentiment, few of them can gain more than sufficient to keep body and soul together. In Galicia it has been estimated that five thousand Jews perish every year from typhus-fever. The Jewish wax-miners in Boryslav, to take but one instance, were forced out of the mines and reduced to utter starvation, for no other reason but because they were Jews. The failure of the harvests in Southern Russia during the last few years has reduced the wage-earners in that part of the country to the position of dependants upon the charity of others; but the Jews who live there in such large numbers do not even benefit from the assistance sent by the government. Similar conditions prevail almost continually in the rest of the Russian pale and in Roumania. The standard of life has naturally been lowered among these people and their general *morale* has not come out of the trial unscathed.

Nor must it be forgotten that the violent dislocation of hundreds of thousands of people, such as has taken place among the Jews during the last quarter of the nineteenth century, has naturally disturbed existing economic conditions, not only among the Jews themselves, but also among those into whose midst they came. These outcasts from Eastern Europe did not come to virgin soil as did the Pilgrim Fathers, but to cities and towns which were already filled with a proletariat engaged in the eager fight for life. The Jews of Berlin, Paris, London, and New York, had their hands full with the proper care of the needy ones already in their midst. 509

It is a mistake to suppose that the Jews as a people are rich. The proletariat among them is proportionately much larger than it is among other people; and thus it came about that the Jewish quarters in all the large cities were already well filled when they were (almost at a moment's notice) called upon to receive double or triple the number they already held. The actual number of the Jewish poor was thereby greatly increased; for many a family that had been wealthy or in easy circumstances in Russia, Galicia, or Roumania, had been reduced to want and been compelled to take its place among those who needed the help of their brethren. This help was freely and cheerfully given all the world over. Great sacrifices were made by the richer Jews to meet the pressing needs of the hour, and, with no help from the outside world, excepting the London Mansion House Fund in 1882, the thousands and tens of thousands of immigrants were cared for. The Jewish charitable organizations, the development of which has been during the latter half of the nineteenth century the brightest spot in Jewish communal life, rose to the demands of the occasion, and the more than princely munificence of Baron and Baroness Maurice de Hirsch, in regard to the Russian Jews, may justly be looked upon with pride.

New Ghettos, however, were formed in nearly all the cities to which these immigrants came; and this name for the habitat of the poorer Jews became again familiar, aided by the popularity which some modern novelists had given to it. In the Middle Ages and down to our own time the Jews had been forced by the state to live apart in such Ghettos; sometimes for their own protection, sometimes to 510 preserve the outside world from contact with them. The modern Ghetto is a voluntary gathering of the Jews for the purpose of mutual help and from a feeling of reciprocal obligations. To the outside observer it presents an unsightly appearance; it is the abode of poor people, and its population is usually strange in dress, manners, and speech. The sweating system (which in one form or another is to be found in all these Ghettos) has been a dreadful incentive towards grinding the face of the poor; and the results of too great a hoarding are often quite apparent; so that the general morality of the Jews in these Ghettos has suffered in consequence. A people ignorant of the language of their new home are a prey to the evil-intended, who make use of their ignorance for their own commercial and political advancement. This has been notably seen in the city of New York, where a lax city government has permitted the vampires of society to fasten their fangs upon the Ghetto and to produce conditions which call for the active interference of all those forces which seek to stamp out crime and vice. But, on the other hand, to one who is acquainted with the inner life of the Ghetto the virtues which have hitherto characterized the Jews—industry and sobriety—are still to be found there; much more frequently than in those parts where the richer classes congregate, and whose wealth enables them to withdraw their doings from the public gaze. Its members are as industrious as bees in a hive; and though extremely litigatious, drunkenness is unknown and actual crime is comparatively rare.

In order to correct the abuses of the Ghetto, two things are absolutely necessary—the increase of the actual number of Jews there must be stopped, and the crowding into certain distinct fields of work must be brought to an end. A determined effort has already been made to force the new immigrants 511 into less crowded parts of the land to which they come. In this country this is being done by the United Hebrew Charities, and notably by the B'nai B'rith. A distinct clannish feeling has, however, to be overcome, and a fear of venturing into an unknown country where the immigrant will be surrounded by people who do not understand his peculiar social and religious customs.

That the Jew has taken by preference to certain branches of trade and work is due to the fact that anti-Jewish legislation has for centuries closed many walks of life to him, and the guild organization excluded him rigorously from many spheres of activity. Then, too, his richly developed home life has induced a certain distaste for occupations which take the wage-earner out of his home and away from his family. That, however, these inherited instincts can easily be overcome is clearly seen whenever the occasion offers. Even in Amsterdam, where three-fourths of the diamond industry is in the hands of Jews, there are to be found Jewish cobblers, cigar-makers, plumbers, carpet-weavers, mattress-makers, watch-makers, etc. In the East End of London there are, it is true, ten thousand Jews who are engaged in the clothes-making trades, but the rest of the forty thousand Jewish wage-earners of this quarter are scattered over all possible branches of work—masonry, metal-working, textile industries, furniture-making, cap-making, and the like. The same is true of New York, where, although the number of Jews employed in the tailoring industries is disproportionately large, the following list of Hebrew unions shows how far afield the Jewish workman has gone: Cap-Makers, Cap-Blockers, Shirt-Makers, Mattress-Makers, Purse-Makers, Liberty Musical Union, Jewish Chorus Union, Jewellers' Union, Tin-Smithers' Union, Bill-Posters, Waiters' Alliance, Architectural Ironworkers, Hebrew 512 Typographical Union, Tobacco Cutters, Paper-Makers, Bookbinders. The same is relatively true of all other countries where Jews live in large numbers.

It is a popular misconception that the Jew has an innate distaste for agriculture. His continued commercial life, forced upon him for many centuries, has, it is true, disaccustomed the Jew to the life of a tiller of the soil. But the Jewish state was largely an agricultural one; the legislation of the Bible and the later Law Books was clearly intended for an agricultural people; and Jews have never shown an unwillingness to return again to the soil. In Southern Russia there are to-day 225 Jewish colonies with a population of 100,000. In Palestine there are now more than twenty colonies with a population of more than 5000, and similar agricultural colonies have been established at various times in the United States, Canada, and the Argentine Republic. In many cases, it is true, these colonies have not yet become self-supporting, but this has been due in a large measure to maladministration and to the peculiar conditions under which the colonies were founded.

It cannot be denied that a goodly part of the Jewish proletariat belongs to the Socialist party. The whole Biblical system is in itself not without a Socialist tinge; and the two great founders of the modern system, Lasalle and Marx, were Jews. It is no wonder that in Russia many of the leading anarchists were of the Jewish race, for the Jew suffered there from the evils which Nihilism was intended to correct ten times more than did his fellow-Russian. But the Jew is by nature peace-loving; and under more favorable circumstances, and with the opportunity of a greater development of his faculties, Socialism in his midst has no very active life; the Jew very soon becoming an ardent partisan 513 of the existing state of affairs.

INTERNAL RELIGIOUS DEVELOPMENT

The facility with which the Jews attach themselves to changed circumstances stands out characteristically through their whole history. It might, indeed, be said with some show of truth that this pliability is the weak side in the Jewish character. The readiness of the Jew to be almost anything and not simply his own self has been one of the factors producing a certain ill will against him. Disraeli was the most jingo of all imperialists in England; Lasker, the most ardent advocate of the newly constituted German Empire. This pliability is the result of the wandering life he has led and the various civilizations of which he has been a part. He had to find his way into Hellenism in Alexandria, into Moorish culture in Spain, into Slavism in Russia and Poland. When the first wave of the modern spirit commenced to break from France eastward over the whole of Europe, it reached the Jew also. While in France the new spirit was largely political, in Germany it was more spiritual. In its political form as well as in its spiritual form it reacted not only upon the political condition of the Jew, but especially upon his mental attitude. The new spirit was intensely modern, intensely cosmopolitan, intensely Occidental, and intensely inductive. The Jew had preserved to a great degree his deductive, Oriental, particularistic, and ancient mode of thought and aspect of life. The two forces were bound to meet. As a great oak is met by the storm, so was Israel set upon by the fury of this terrible onslaught. It is of interest to see in what manner he emerged from this storm—whether he has been able to bend to its fury, to lose perhaps some of his leaves and even some of his branches, but to change only in such a 514 way as to be able to stand upright again when the storm is past.

This great clash of ideas has produced what is known as the Reform movement. It had its origin in Germany under the spiritual influences of the regeneration of German letters produced by such men as Goethe, Schiller, Herder, Lessing, and Mendelssohn. It was aided in a large measure by the fact that the government in Germany, although distinctly opposed to anything which militates against the established order of things, mixes itself very seldom in the internal affairs of the Jewish communities. This Reform movement has colored the religious development of Judaism during the three-quarters of the century which is past. The heat of the controversy is now wellnigh spent. Many of those who stood in the front ranks have passed away, so that a more just estimate of its value can be reached. It was a period of tremendous upheavals, of great physical as well as mental pain. Many a congregation was split in twain, many a family disrupted. At one time it looked as if two distinct bodies of Jews would emerge from the struggle, and the union of Israel be destroyed forever. A common enemy—anti-Semitism—joined the two forces together for a common defence; and the danger of such a split is now fairly a thing of the past.

The latter half of the eighteenth century found the Jews of Middle Europe at the lowest intellectual and social point they had up till then reached. The effect of the long Jewish Middle Ages was plainly visible. Few great minds lit up the darkness, and an intellectual torpor seems to have spread its pall over everything. A passive uniformity of practice prevailed in all the communities, whether Sefardic (Spanish and Portuguese) or Ashkenazic (German and Polish); a uniformity, because actual intellectual life had been made to run in one single groove. The Talmud had been the great saving of Judaism in 515 the past. In the intellectual exercise which its study necessitated, the mind of the Jew had been given a field in which it could rove at will. Living apart from the rest of the world, with a wide jurisdiction over his own affairs, Talmudic law in its latest development was still the law supreme for the Jew. The Jewish Ghetto had everywhere the same aspect; the language in common use was, in all the Ashkenazic communities, the Judæo-German in one of its various forms. A certain severity in evaluating those things which were part of the outside world made itself felt. There was ample time and ample occasion for the practice of all those forms and ceremonies with which the Judaism of the Middle Ages had willingly and gladly fenced in the law. There had been little occasion for the practice of the beautiful arts or for the cultivation of letters. Life in the Ghetto was not necessarily gloomy, but it was solemn. The law was not felt as a burden, but it required the whole individual attention of those who bound themselves by it, from early morn till late at night, from the cradle to the grave. There was no place for things that come from outside, because there was no time to devote to them.

But the new European spirit in its French political form was knocking hard at the gates of the Ghetto. Little by little it made its way here and there, into all sorts of nooks and corners. It was bound in time to be heard by some of those living behind these gates. The name of Moses Mendelssohn is indissolubly connected with the history of German Judaism during the latter part of the eighteenth century. It was due to him that a vehicle was found which the new spirit could use. Himself a strictly observant Jew, he felt the pulse of the new era. The friend of Lessing and of Nicolai, he entered fully into the revival which was then making itself felt. Through his translation of the Pentateuch (1778, 516 etc.) into High-German, he prepared the way for the further introduction of German writings to the Jewish masses. This was bound to bring with it a larger culture and a greater freedom of thought. Many of his friends, such as Wessely, Hertz-Homberg, and David Friedlander, stood by his side in this

work. With the introduction of the German language and German literature, better and more modern schools were needed in which secular education should go hand in hand with the former one-sided religious training. David Friedlander was the first to found a school in the modern sense of the term; and he was followed by Jacobson in 1801, at Seesen, Westphalia, and at Cassel, and by Johlson, at Frankfort, in 1814. Between the years 1783 and 1807 such modern Jewish schools arose in Germany, Austria, Denmark, France, and even in Poland. Literature was cultivated, and the first Jewish journal (though still in Hebrew) was published in Königsberg, 1783 (*Hameassef*—the Collector). The *Gesellschaft der Freunde*, founded in Berlin in 1792, was distinctly intended for the spread of this modern culture; yet Mendelssohn's own position was quite an untenable one. He was a thoroughly Orthodox Jew in practice, but his mental attitude was that of a modern German. He was and he was not a reformer. He held that it mattered little what philosophical position a Jew held, the Jew must observe all the ceremonies connected with the faith; these were binding upon him by the mere fact of his having been born into the Covenant. It is therefore no wonder that his translation was put under the bann in Hamburg, Altona, Fuerth, Posen, etc. His friend Friedlander wished to make of the synagogue a sort of Ethical Culture Society; and Jacobson's preaching in Berlin contained very little of what was distinctly Jewish. The salons of Berlin, Königsberg, and Vienna, which were presided over by brilliant women, who were more or less immediate disciples of Mendelssohn, nurtured the cosmopolitan spirit 517
which was bound to be destructive of practical Judaism. That this fruit on the Tree of Knowledge ripened too quickly is seen from the fact that all the descendants of Mendelssohn, Friedlander, and others, led astray by this cosmopolitan spirit and the philosophic presentation of Christianity by Schleiermacher, have all become devoted members of the Lutheran Church and have been completely lost to Judaism.

It was natural that these new influences should influence also the training of the modern rabbis. Secular education had been introduced into primary schools, and in some places—as, for instance, Lombardy, in 1820—the government demanded a certain amount of secular knowledge from the candidates for rabbinical positions. The Jew also desired that his leaders should have the same training as he gave his children, that they should be educated in the same atmosphere in which he himself had grown up. The old rabbinical seminaries, or Yeshibot, in which the instruction was entirely on Talmudic lines, had already run their course; the study had been found insufficient by the pupils themselves, and the schools of Frankfort, Fuerth, Metz, Hamburg, and Halberstadt had all been closed for want of students. The need of a modern seminary was felt quite early during the century; and in 1809, a Lehrer-Seminar was founded in Cassel. The earliest regular seminary for the training of rabbis, however, was founded in Padua in 1829. In Germany attempts had been made in the year 1840, but these attempts were unsuccessful. The first modern seminary was not founded in Germany until the year 1854 (Breslau). Then followed Berlin, in 1872; Cincinnati, in 1873; Budapest, in 1876. Similar institutions exist now in London, Paris, and Vienna.

In the first convulsions of the Mendelssohn period the way was paved for the second period of the 518
Reform movement which covers the first quarter of the nineteenth century. The real issues touched the central point of Jewish life, the synagogue. It is interesting to note that during this period the chief questions were not so much theological as æsthetic. The æsthetic side of life could not be largely cultivated in the Ghetto; and the form of the service had greatly degenerated. In the course of centuries, so many additional prayers and songs and hymns had been added that the ritual was largely overburdened, and often tended rather to stifle than bring out the religious sense they were intended to conserve. Contact with the outside world created and fostered this æsthetic sense, and the influences of the writings of such men as Lessing and Mendelssohn was largely in this direction. As this æsthetic sense made its way into the homes, so also did it carve out its way into the synagogue. Demands were heard for a shorter service; for the organ to accompany the chanting of the reader; for the German language in some of the prayers and for the German sermon. Each point was bitterly contested; for the Orthodox wing had before it the wholesale apostasy of the Salon Jews. In order to introduce the vernacular into the service and into the sermon, private synagogues were opened by small coteries in Cassel (1809), Seesen (1810), Dessau (1812), and Berlin (1815). In Southern Germany the use of the vernacular was introduced between the years 1817 and 1818, also in Hungary through the influence of Abraham Chorin. In some countries the government gave its active aid. In Vienna, in 1820, German

was made obligatory, and as early as 1814 Danish in Copenhagen. The greatest changes, however, were made in the Hamburg temple (under Kley and Salomon, 1818), where not only the service was made more æsthetic and the German language introduced, but certain prayers referring to the 519 Messianic time were either omitted or altered. No wonder, then, that the Orthodox rabbis in Germany, with the support of the rabbis in various other countries, protested against such a course. The government even looked askance at these Reform proceedings, and in 1817 and 1823 ordered a number of these private synagogues to be closed. A further cause for displeasure was the introduction in 1814 of the confirmation of children in German, to replace or supplement the old Barmitzvah, a clear imitation of the ceremony in the Protestant Church of Germany. Despite opposition, however, the confirmation found its way into Berlin, Hamburg, Frankfort, Cassel, Copenhagen, etc.

This æsthetic revolution in the synagogue could not, however, long remain the only outward sign of the new life. The great weakness of the Reform movement has been that it has lacked a philosophic basis; and, as in its first beginnings, with the exception of Hamburg, it took little note of the changed point of view from which those who fought for reform looked at the old theological ideas. Æsthetic reform was the work largely of individual persons and individual congregations. No attempt had been made either to formulate the philosophic basis upon which the reform stood, or to provide a body which should regulate the form which the new order of things was to take on. Two attempts were made to remedy these evils, both closely related one to the other.

The first was crystallized in what is now known as the "Science of Judaism"; by which is meant the untrammelled, scientific investigation of the past history of the Jews. The want of this was severely felt just in those centres where reform had taken up its abode; and those who assisted at its birth did so with the avowed purpose of getting at the real kernel of Judaism by such investigation, and of freeing 520 that kernel from the accretions of ages. They saw also that some means had to be found by which the result of these researches could be brought before the people. The Mendelssohn period had also felt this; but its organ had been written in Hebrew, and could not, therefore, appeal to those who wished for the intellectual advancement of the Jews upon modern lines. The Society for Culture and the Science of Judaism in Berlin (founded 1819) started a journal, with L. Zunz as editor. Though it only lived during the years 1822 and 1823, it was the forerunner and the model for many of its kind that followed after. In 1835 appeared Geiger's *Scientific Journal for Jewish Theology*, and in 1837 a regular weekly was established by L. Philippson, the *Allgemeine Zeitung des Judenthums*. Around these and other journals which quickly sprang up there gathered a coterie of historians, philologists, and students of literature which in the fifty years between 1830 and 1880 has built up a science which has extended its investigations into every corner of Jewish life in the past, and has followed to their sources the various lines of development which have appeared from time to time. A full estimate of what has been done will be apparent only when the great Jewish Encyclopædia will be ready which is now in course of publication in New York. Zunz, Geiger, Krochmal, Rapoport, Frankel, Löw, Steinschneider, Graetz, Luzzatto, and Reggio are only a few of the names of those who gave up their lives to this work. Most of the early labor of these men was not dry-as-dust investigation pure and simple, but was intended to have a bearing upon the actual life, upon the burning questions which were then agitating Jewish thought. This is clearly seen in the journal of which Zunz was editor, and in his *Gottesdienstliche Vortraege*, the basis of nearly all the work done after him, but which was evidently written to give the history of preaching in the synagogue in order to justify the shortening of the ritual 521 and the introduction of the German sermon.

The second attempt was to found or create some central body which would remove the purely personal element out of the Reform movement. In 1837 Geiger had called his friends to a conference at Wiesbaden for the purpose of formulating what they considered to be the essence of Judaism. In 1844 a second such rabbinical conference was held in Brunswick, largely at the suggestion of L. Philippson. Similar conferences were held at Frankfort in 1845, and at Breslau in 1846; for in the mean time the Reform Genossenschaft had been created at Berlin, which went beyond all previous attempts and demanded some positive statement of the theological position which it and its friends occupied. The Frankfort assembly not proving satisfactory, the Berlin society went ahead to establish its own synagogue; added a Sunday service (which in a short while became the only service), and under the guidance of S. Holdheim definitely broke with traditional Judaism, removing nearly all the

Hebrew from its service, abbreviating the prayer-book still further, and diminishing the number of observances. In Europe this Reform synagogue in Berlin has gone to the furthest extreme; and though it has in a measure kept its members within the pale of Judaism, it has neither been a great power nor has it found imitators. The hope was generally expressed that a more general synod would be held, to which the previous conferences were looked upon as simply preparatory. The year 1848, however, put a stop to all normal development; and it was only after a number of years that the question was again taken up. In 1869 a synod was, indeed, held at Leipsic, attended by eighty-one members; and in 1871 at Augsburg, attended by fifty-two, both under the presidency of Prof. M. Lazarus. These synods dealt, in a spirit of moderate reform, with questions relating to the ritual, synagogue observance, the 522 admission of proselytes, etc. The general stand there taken would to-day be looked upon as conservative; dogmatic questions were hardly touched upon excepting so far as they recognized the principle of development in Judaism both as a religious belief and as a form of religious exercise. It was fondly hoped that these synods would become a court, which would define and regulate whatever questions might arise. But it was not to be. The synod represented only a part of the Jewish world even in Germany. Not only did the large body of the Orthodox stand aside, but even the so-called Conservatives left the conferences, as they could not agree with some of the resolutions accepted there. In addition to this, the Franco-Prussian war diverted the attention of all German citizens; and ten years later the anti-Semitic movement succeeded in driving the Jew back into himself. Jewish religious life in Germany has therefore remained stationary since that time, the Orthodox and Conservative parties being largely in the ascendant, leaving to another land—America—the task of carrying further the work which it had commenced. Yet, in spite of this arrested development, the Reform movement has had a great influence also upon Orthodox Jews in Germany. It produced the so-called historical school, which has the Breslau Theological Seminary for its centre; and it called forth by way of opposition the neo-orthodoxy of S. R. Hirsch, of Frankfort, which seeks rather to understand the depths of the law than simply to follow it in compliant obedience.

The æsthetic movement of the earlier period has also left its traces, and especially in the Conservative congregation has succeeded in introducing a service more in consonance with our modern ideas of worship.

In 1840, under the influence of the movement in Germany, the attempt was made to introduce a 523 certain reform in the service of some of the London synagogues. The measure demanded was exceedingly small—the shortening of a few prayers and the omission of others, which were not supposed to be in consonance with present ideas. The Orthodox party did not, however, see its way to grant these requests; and, when the Reformers protested, established their own synagogue, and issued their own prayer-book, they were immediately placed under the bann both by the Sefardim and the Ashkenazim. This congregation has not been of much importance, and since its inception has made no further changes. Compared with the Reform in America, the English movement would still be classed as thoroughly conservative.

It was in the United States that the Reform movement developed its full capacity and bore its most perfect fruit. In a new land, which was untrammelled by traditions of the past, and where the congregational system became the basis of Jewish communal life, the ideas which the German Reformers had sown had a most fruitful ground in which to grow. It cannot be said that the Reform movement here was actually started by the Germans, for already, in 1825, one of the congregations in Charleston, South Carolina, made up almost entirely of Sefardic Jews, had developed “The Reformed Society of Israelites”; and the formation of the society seems to have been due, not only to the demand for an æsthetic service, but to an attempt to formulate a creed which should omit all reference to the coming of the Messiah, the return to Palestine, and the bodily resurrection. This attempt at formulating a Theistic Church, however, was unsuccessful; and it was not until the advent from Germany in the 50’s and 60’s of rabbis who had been influenced by the movement in Germany that reform commenced to make itself felt here. Merzbacher in New York, Isaac M. Wise in Albany and 524 Cincinnati, S. Hirsch in Philadelphia, David Einhorn in Baltimore, are only a few of the names of those who fought in the thick of the fight. About the year 1843 the first real Reform congregations were established, the Temple Emanu-el in New York and Har Sinai in Baltimore. It cannot be my purpose here to trace the history of the movement in this country; suffice it to say that the

untrammelled freedom which existed here very soon played havoc with most of the institutions of the Jewish religion. Each congregation and each minister being a law to itself, shortened the service, excised prayers, and did away with observances as it thought best. Not that the leaders did not try, from time to time, to regulate the measure of reform to be introduced, and to evolve a platform upon which the movement should stand. Rabbinical conferences were held for that purpose in Cleveland (1856), Philadelphia (1869), Cincinnati (1871), and Pittsburg (1885). While in the earlier conferences the attempt was made to find some authoritative statement upon which all parties could agree, in the subsequent ones the attempt was given up. They became more and more meeting-places simply for the advanced Reform wing of the Jewish Church. The position of this wing of the Reformed synagogue may best be seen in the declaration of principles which was published by the Pittsburg conference. It declared that Judaism presents the highest conception of the God idea; that the Bible contains the record of the consecration of the Jewish people; that it is a potent instrument of religious and moral instruction; that it reveals, however, the primitive ideas of its own age; that its moral laws only are binding; and that all ceremonies therein ordained which are not adapted to the views and habits of modern civilization are to be rejected; that all Mosaic and rabbinical laws regulating diet, priestly functions and dress, are foreign to our present mental state; that the Jews are no longer a nation, and 525
therefore do not expect a return to Palestine; that Judaism is a progressive religion, always striving to be in accord with the postulates of reason; that the belief in bodily resurrection, in the existence of a hell and a paradise, are to be rejected; and that it is the duty of Jews to participate in the great task of modern times to solve on the basis of justice and righteousness the problems presented by the transitions and evils of the present organization of society. Such a platform as this could not fail to arouse intense opposition on the part of the Orthodox Jews, and to lose for the conference even some of its more conservative adherents. As in Charleston, in 1825, a platform of Theism was here postulated, which was bereft of all distinctively Jewish characteristics, and which practically meant a breaking away from historic Judaism. This position of the advanced Reformers is also manifested in the stand which they have taken in regard to the necessity of the Abrahamic covenant. At a meeting of the Central Conference of American (Reformed) Rabbis, held at Baltimore in 1881, a resolution was passed to the effect that no initiatory rite or ceremony was necessary in the case of one desiring to enter the Covenant of Israel, and that such a one had merely to declare his or her intention to worship the one sole and eternal God, to be conscientiously governed in life by God’s laws, and to adhere to the sacred cause and mission of Israel as marked out in Holy Writ.

The service in Reform synagogues in the United States has kept pace with this development of doctrine, or rather with this sloughing-off of so much that is distinctively Jewish. The observance of the second-day festivals has been entirely abolished, as well as the separation of the sexes and the covering of the head in prayer. The ritual has been gradually shortened, the ancient language of prayer 526
(Hebrew) has been pushed further and further into the background, so that in some congregations the service is altogether English; and in a few congregations an additional service on Sunday, intended for those who cannot attend upon the regular Sabbath-day, has been introduced. Only one congregation, Sinai in Chicago, has followed the old Berlin Reform synagogue and has entirely abolished the service on Friday night and Saturday morning. But whatever criticism one might like to offer on the Reform movement in the United States, it deserves great praise for the serious attempt it has made to understand its own position and to square its observance with that position. It has also been most active in its modern institutional development. It has certainly beautified and spiritualized the synagogue service; it has founded a Union of American Hebrew Congregations, and a seminary (Hebrew Union College in Cincinnati). It has published a Union Prayer-book and a Union Hymn-book, and has given great care to the development of the Confirmation and the bettering of the Sunday-school. It has tried to make the synagogue a centre for the religious and spiritual development of its members; and it cannot be denied that the very large mass of educated Jews in this country, in so far as they have any affiliation with the synagogue, belong to the Reform wing. But at the same time, it must not be forgotten that there is a very large body of Orthodox and Conservative Jews, whose number has been greatly increased during the last twenty years through the influx of Russian, Galician, and Roumanian Jews. It would be outside of my province were I to attempt to criticise either the work or the results of Reform Judaism in this country. But it is a question in the minds even of some of the leading Reformers themselves how far success has been attained in developing the religious sentiment

of their people in the direction of a pure Theism uncolored by any Jewish, or, as they call it, Oriental observances. They themselves confess that the Sunday-service movement has not developed as they had hoped it would, and a number of them feel that in weakening the hold which specific Jewish observances have always had on the Jewish people, they are doing away with one of the most powerful incentives to the rekindling of the religious flame among the Reformed Jews. 527

Reform Judaism without some centrifugal force is bound to continue on the road it has once taken. The logical outcome of the principles formulated at the Pittsburg conference is a gradual development into an ethical Theism without any distinctive Jewish coloring. The leader of advanced Reform Judaism in this country has recently said that Judaism must be recast along the lines of a universal ethical religion; that then all distinctive Jewish elements of the synagogue symbolism will pass away, and that such a denationalized Jewish temple will seek a closer alliance with Unitarianism and Theism, and with them, perhaps in a few decades, will form a new Church and a new religion for united humanity. That such a tendency is inherent in Reform Judaism is seen also in the formation of the Society of Ethical Culture in New York. The leader of this movement is the son of a former prominent rabbi of the leading Reform congregation in this country. In seeking to bring out the underlying ethical principles of Judaism, he has gone entirely outside the pale of the ancient faith; and the movement would not concern us here were it not that nearly all the members (at least of the parent society in New York) are Jews, whose evident desire it is not to be recognized as such, at least so far as religious ceremonies and social affiliations are concerned. The society does not even bear the name Jewish, but with a certain leaning towards liberal Christianity tries to find a basis for the morality and ethics of the 528
old synagogue outside the sphere of supernatural religion. While the Ethical Culture Society has been quite a power in certain lines of charitable and educational work, it may reasonably be questioned whether it has any future as a form of Church organization. The inborn longing of man for some hold upon things which are supernatural will lead many of its members to seek satisfaction elsewhere. That they will seek it in the Jewish synagogue is hardly probable, seeing how the racial and other ties have been broken or at least greatly loosened. They or their children will glide rather into some form of the dominant Church, possibly, in the swinging of the pendulum, into some orthodox form of that Church. I cannot help quoting the words of an intelligent outside observer of the Jewish question, the Right Hon. James Bryce, M. P.: “If Judaism becomes merely Theism, there will be little to distinguish its professors from the persons, now pretty numerous, who, while Christian in name, sit loose to Christian doctrine. The children of Jewish theists will be almost as apt as the children of other theists to be caught up by the movement which carries the sons and daughters of evangelical Anglicans and of Nonconformists towards, or all the way to, the Church of Rome.”

Where, then, is this centrifugal force to be found, which will hold together the various elements in Israel, no matter what their theological opinions may be?

ANTI-SEMITISM

Before attempting to answer this question, a word must be said in regard to the anti-Semitic movement, the recrudescence of which has so profoundly affected the Jewish people during the last twenty years of the nineteenth century. A word only, because the facts are of too recent date to need a 529
detailed statement here. The great master-mind, Zunz, writing in Germany in 1832, believed that persecution for religious belief could not withstand the onslaughts of the new era. Theodore Reinach, some fifty years later, asserted that anti-Semitism was impossible in France. How sadly has a *démenti* been given to the hopes thus expressed, especially in these two countries!

I pass over the outbreaks against the Jews during the early years of the nineteenth century, even the Damascus blood-accusation in 1840, and the forcible baptism of little Edgar Mortara in 1858; they were believed to belong to the old order of things, with which the new, at least in that direction, had nothing in common. I confine myself simply to the modern form of anti-Judaism, which has been dignified with the name of anti-Semitism. It is hard for a Jew to speak of these things with composure or with the judicial mind of a mere chronicler of events. Neither emancipation from without nor

Reform from within has been able to stay the hand of the destroyer of Israel's peace. It has been contended that in most countries the Jews were not ready to be emancipated; that in some the non-Jewish population was not sufficiently advanced to make emancipation effective. The first may be true in regard to the Algerian Jews; the second, in regard to those in Roumania; but it is not true of the other nations on the European continent. Starting in Germany, perhaps as a political move on the part of Bismarck, it spread into Russia, Galicia, Austria, Roumania, and France. In most of these countries it not only found expression in the exclusion of the Jews from all social intercourse with their fellows, but in Russia produced the riots of 1881 and 1882; in Austria and Bohemia the turbulent scene in the Reichstag, and even the pillaging of Jewish houses and Jewish synagogues; in Roumania it received 530
the active support of the government and reduced the Jews there to practical penury; while in France it showed itself in accusations against the Jews which for barbarity could match any that were brought against them in the Middle Ages. The charges against the Jews are varied in their character. In Germany they have been blamed for exploiting the agricultural class and for serving the interests of the Liberal party, forgetting that Leo and Stahl, the founders of the Orthodox party in Prussia, were themselves Jews, and that Disraeli in England was born of the same race. The most foolish accusations on almost every conceivable subject have been lodged against them by such men as Ahlwart, Stöcker, Lueger, and Drumont; and in late years the old and foolish charge that the Jews use the blood of Christian children in the making of Passover bread has been revived, in order to infuriate the populace; despite the fact that popes, ecclesiastics, and hosts of Christian professors have declared the accusation to be purely imaginary and malignant. The false charge that a Jewish officer in France had betrayed secrets of his government was sufficient to unloosen the most savage attacks upon the Jews which the modern world has seen.

The fact which stands out in the whole agitation is not that the charges have been made, in most cases by men who sought in some way or other to fish in troubled waters, but that these charges find a ready echo and a ready response among the people at large. It emphasizes so clearly that the Jews are a defenceless people, with no means of effectually warding off attacks; and though in Germany and Austria societies of Christians have been formed for the purpose of combating anti-Semitism, there is no power which can effectually enter the lists in their behalf. This was notably seen in the great London demonstration of 1882, when the petition signed by the foremost members of Church and state 531
never even reached the Czar, to whom it was addressed.

Among the few bright spots on the world's chart are those countries inhabited by the Anglo-Saxon race. Anti-Semitism is unknown in England (though the attempt has been made to fix the blame for the Boer war on the Jews); and the institutions of the United States have up till now prevented the entrance here of the disease, though in the mild form of social anti-Semitism which debars Jewish children from private schools and Jewish people from clubs and summer hotels, it has insinuated itself into some of the Eastern cities, notably into New York.

ZIONISM

There can be no doubt that next to the Reform movement the profoundest modification of the forces within Judaism has come about during the last years of the century through the rise and progress of the Zionist movement. It has been said by some that Zionism is the expression of Jewish pessimism, by others that it is the highest form of Jewish optimism. I venture to say that it is both. The emancipation of the Jews has not been able to do away with anti-Semitism; history has repeated itself time and time again. When the Jews of a country were few in number and of little influence, they led a tolerably secure existence; but as soon as their number increased and their influence commenced to be felt, anti-Semitism was the effective weapon in the hands of their opponents. In so far, then, as Zionism takes account of this fact, it is pessimistic; for conditions in the future will hardly differ from those in the past. It sees the Wandering Jew of history continuing still his dreary march through the ages, never at rest and never able to effect a quiet and even development of his own forces. It explains 532
this phenomenon from the fact that Israel has in all the changed circumstances striven to maintain its

racial identity, and as this racial identity has a religious side as well, that the two combined may well be called a separate national existence; that a people holding tenaciously to this separate existence, but having no home of its own, must become, when occasion demands, the scape-goat and the play-ball of other forces. It recognizes anti-Semitism as continually existent, and in so far the opponents of Zionism may be right in saying that its rise is the result of the anti-Jewish movement. It is the Jewish answer from the Jewish point of view. On the other hand, Zionism is optimistic in believing that real help for the Jews can only come from within their own body; and that the Jewish question will only be solved when the Jews return to that point in their history whence they set out on their wanderings, and again found a permanent home to which all the persecuted can flee and from which a light will go forth to every nook and corner of Jewry. It does not hope that all Jews will return to Palestine, but it believes that only in a national centre can the centrifugal force be found which will hold the Jews together in the various countries of their sojourn.

When Theodore Herzl, a *littérateur* in Vienna, published in 1897 his pamphlet on the Jewish state, he little imagined that it would call forth an echo in every country in which the Jews were scattered. He was not the first to attempt this solution of the problem. Far-seeing Russian Jews before him had, many years previous to that, propounded this method of dealing with the question, and it had been practically the assumption upon which the Judaism of the past had been built up. Reform Judaism, in relinquishing the hope of a return, and in cutting out from the prayer-book all mention of Palestine and 533 the restoration, broke one of the strongest links which bound the Judaism of to-day with that of the past, and cast aside a great ideal, the realization of which had been a light to the feet of the Jews since the destruction of the Temple. The idea of a “Mission” has taken its place, the preaching of a pure Monotheism.

The Zionist congresses (which have now been held during four successive years) have found the platform, so often sought for in vain during the nineteenth century, upon which all Jews, regardless of theological opinions and of economic theories, can stand. They represent the old unity of Israel; for Orthodox, Conservative, Reform, and even the purely racial Jew are to be found there as well as in the Zionist societies which have grown up in every Jewish community, whether in Europe or in Africa, in North or in South America, even in the distant Philippines. The Orthodox Jew must be, by his very profession, a Zionist; but he often doubts whether the plan as formulated by Dr. Herzl is feasible, and holds himself aloof, waiting for the realization of his hopes at the hands of others, or for some supernatural sign of divine assistance. The very fact that the Jewish opponents of Zionism (and they are the only opponents it has) come from various parts of the Jewish camp is in itself a proof of the above statement. The Orthodox complain that some of the leaders of the movement are not sufficiently Jewish; the Reform, that some are too Jewish. That this opposition is exceedingly strong cannot be denied. The demand made that the Jew should assert himself first and foremost as a Jew has been distasteful to many who were soaring in the mystic hazes of Universalism, or who had hoped to get out of Judaism as it were by the back door, without being seen by the world at large.

But even in those circles which do not formally affiliate with Zionism, or who at times even 534 oppose it, there has of late years been a very strong revival of Jewish feeling and a movement towards a stronger expression of that feeling. Germany is honeycombed with societies for the study of Jewish literature; the Hebrew language has been revived, notably in Russia, not only as a form of literary expression, but also as a vehicle of social intercourse; France has its Society of Jewish Studies; America and England have their Jewish Historical Societies, and their Jewish Chautauqua movements; Jewish national societies have sprung up among the students of German and Austrian universities—all influences—tending in this one direction.

THE TWENTIETH CENTURY

As we look ahead into the century which is now opening and cast our eye over the forces which the Jews will bring into its life, we can easily see that these forces tend in various directions.

We have first the Orthodox wing of the Jewish Church, which stands upon the broad basis of what the past has evolved. It holds firmly to the inspiration of the biblical word and the divine character of its interpretation as handed down in the oral law; it tries to regulate its life by Talmudic ordinances as evolved in the latest law books, and is unwilling to make any but æsthetic concessions to changed circumstances, believing that we must adhere strictly to all the time-honored ceremonies of the synagogue. At its side stand the Conservatives, who are willing to make some concession to present demands, but believe that these concessions should be most sparingly and grudgingly made, and who theologically, at least in theory, occupy the same position as do the Orthodox. It is safe to say that the greater number of Jews in the Western European states belong to this wing of the synagogue. Between 535 the Conservatives and the Ethical Culturists stands the Reform party, more numerous in the United States than anywhere else, whose position it is hard to define and in whose midst there are various shades of opinion and of practice. All the Reformers have openly or tacitly broken with Talmudic Judaism—the more conservative among them seem to believe that a new Judaism can be built up upon the Bible, only without its traditional interpretation; while the advanced body do not even look upon the Bible as binding, but merely as a starting-point for a further development. They do not consider the Bible as inspired in the old accepted sense of the term; they welcome biblical criticism as an aid to the understanding of the early history of their people; they do not believe in the special election of Israel, and have a well-defined abhorrence of anything like a creed. They are practically Theists with a Jewish racial coloring. Nor do they believe in the coming of a personal Messiah; rather, in the advent of a Messianic time in which righteousness and good-will shall prevail and all the earth acknowledge the one God. To bring about this time is, according to them, the Mission of the Jew—a phrase very current in these latter days, the fulfilling of which has been made the pretext for dejudaizing Judaism, so as to make it acceptable to non-Jews. Mr. Oswald John Simon, of London, has even gone further. He believes that if the Reform party is earnest in its pretensions, it ought—as it did once before in its history—to become an active missionary power. A few years ago he attempted to found a Jewish Theistic Church, which should in no way be colored by Jewish ceremonial. The movement was, of course, a failure. The original attempt, some nineteen hundred years ago, led to the founding of the Christian Church, and Jews themselves have suffered too much from missionaries of other faiths to 536 take to this work with pleasure. But, in addition to these, there is also a large body of Jews whose connection with the synagogue is purely nominal, and who know of it only when they need the services of its sanction or the respectability of its connections. The hold which the Jewish Church has upon them is small indeed, and many of them hope, in the twentieth century, to doff their Jewish gaberdine. The open or concealed pressure of anti-Semitism (particularly on the continent of Europe) which makes it impossible for the Jew as such to attain to social distinction or political position will drive most of these into the arms of the dominant Church of the country in which they live. In a remarkable article published in the *Deutsche Jahrbücher* of October, 1900, a writer who uses the *nom de plume* of Benedictus Levita openly urges those of his fellow-Jews who have become estranged from the synagogue to have their children baptized, in order that they may not suffer as their parents have, but may become really believing Christians, since their affiliation with the Christian Church has become necessary in the modern Christian state. Another German Jew at about the same time advises his brethren to declare themselves “Confessionslos,” so as to become lost, not in Christianity, but in “Deutschtum.” A similar request was made to the Jews of Roumania, in 1900, by the historian Xenopol of Bucharest. There is little fear that this advice of wholesale apostasy will find many adherents, notwithstanding the fact that an unusually large number of conversions have taken place in Germany and Austria, due wholly to pressure from without rather than to conviction from within. The defection even of comparatively large numbers can, however, hardly affect the Jewish cause as a whole; for these numbers living on the periphery, or even beyond it, have been of little service to the Jewish cause; and all through the ages Jews have made just such contributions as these to the general 537 society in which they lived.

There can be no doubt that Zionism is a strong protest against these weaklings, and that the coming century will witness the Jews divided into two camps not necessarily hostile to each other, the Zionists and the Non-Zionists—those who plead for a conservation of the old energy and the old ideals, and those who look forward to the disintegration of Judaism and its gradual passing away into other forces. That Judaism can only conserve its force if that force is attached to a racial and national basis is seen clearly in the fact that just those Jews in Germany who have been most loudly clamorous against the Zionists propose to have now what they call a German “Judentag,” which can certainly mean nothing unless it become Zionist in its tendency.

Confident in this hope, we of the House of Israel look calmly into the future. The message of the prophet of old is full of meaning for us: “Thus saith the Lord God: behold I, even I, will both search my sheep and seek them out, as a shepherd seeketh out his flock in the day that he is among his flock which is scattered, and I will deliver them out of all places where they have been scattered in the cloudy and dark day.” We can echo the sentiments expressed by a Christian Zionist, George Eliot, many years ago: “Revive the organic centre; let the unity of Israel which has made the growth and form of its religion be an outward reality. Looking towards a land and a polity, our dispersed people in all the ends of the earth may share the dignity of a national life which has a voice among the peoples of the East and the West—which will plant the wisdom and skill of our race so that it may be, as of old, a medium of transmission and understanding. Let that come to pass, and the living warmth will 538
spread to the weak extremities of Israel, and superstition will vanish, not in the lawlessness of the renegade, but in the illumination of great facts which widen feeling and make all knowledge alive as the young offspring of beloved memories.”

Richard J. H. Gottheil.

539

FREE-THOUGHT

The history of religion during the past century may be described as the sequel of that dissolution of the mediæval faith which commenced at the Reformation. The vast process of disintegration proceeds by degrees, is varied by reactionary effort, and gives birth to new theories in its course. In our day the completion of the process and a new departure seem to be at hand. A sharp line cannot be drawn at the beginning of the last century, the leaders of religious thought in the seventeenth and eighteenth centuries having been to a great extent the leaders, and their works the text-books, of the nineteenth.

At the Reformation Protestantism threw off the yoke of Pope and priest, priestly control over conscience through the confessional, priestly absolution for sin, and belief in the magical power of the priest as consecrator of the Host, besides the worship of the Virgin and the saints, purgatory, relics, pilgrimages, and other incidents of the mediæval system. Ostensibly, Protestantism was founded on freedom of conscience and the right of private judgment. In reality, it retained Church authority over conscience in the shape of dogmatic creeds and ordination tests. It besides enforced belief in the plenary inspiration of the Bible, by which the exercise of private judgment was narrowly confined. Not for some time did it even renounce persecution. In grimly Calvinistic Scotland a boy was hanged for impugning the doctrine of the Trinity at the end of the seventeenth century. The Anglican Church, 540
suspended by the will of the Tudor sovereigns between Catholicism and Protestantism, oscillated from side to side, producing by one of its oscillations the great civil war. It burned heretics in the reign of James I. All the Protestant Churches except the Baptists, who at first were objects of persecution, fell under the dominion of the state, which repaid them for their submission and support by endowments, temporal privileges, and persecution of dissent.

Though Protestantism produced a multitude of sects, especially in England at the time of the Commonwealth, hardly any of them were free-thinking or sceptical; those of any importance, at all events, were in some sense dogmatic and were anchored to the inspiration of the Bible. Nor is it easy to convict Hobbes, bugbear of the orthodox as he was, of scepticism or even of heterodoxy. The expression of heterodox opinions, indeed, would have been a violation of his own principle, which makes religion absolutely an affair of the state, to be regulated by a despotic government, and confines liberty to the recesses of thought. It is true that in making religion a political institution, variable at a despot's will, he covertly denied that it was divine.

Under the Restoration religious thought and controversy slept. The nation was weary of those subjects. The liberty for which men then struggled was political, though with political liberty was bound up religious toleration, which achieved a partial triumph under William III.

The Church of Rome, to meet the storm, reorganized herself at the Council of Trent on lines practically traced for her by the Jesuit. A comparison of Suarez with Thomas Aquinas shows the change which took place in spirit as plainly as a comparison of the Jesuit's meretricious fane with the Gothic churches shows the change in religious taste. Papal autocracy was strengthened at the expense 541
of the episcopate, and furnished at once with a guard and a propagandist machinery of extraordinary power in the Order of Loyola. That the plenary inspiration of the Bible in the Vulgate version, and including the Apocrypha, should be reaffirmed was a secondary matter, inasmuch as the Church of Rome holds that it is not she who derives her credentials from Scripture, but Scripture which depends for the attestation of its authority upon her. She now allied herself more closely than before with the Catholic kings, with Philip II., and afterwards with Louis XIV., who paid her for her support of political absolutism by sanguinary persecution of heretics. She hereby parted with her Hildebrandic supremacy over the powers of the world, though she did not, like the Anglican Church, recognize the divine right of kings. The liberal and peace-making movements which had been set on foot, or were

afterwards set on foot, within her pale, such as the Oratory of Divine Love, which held justification by faith and wished to compromise with the Protestants, were effectually put down. Jansenism, when it appeared, with its half-Calvinistic theory of Grace, shared the same fate. Gallicanism afterwards, having nationality to back it, was more successful. But it brought no freedom of conscience; it was merely a repartition of the despotic power over conscience between the King and the Pope.

In Spain, and for the most part in Italy, Rome, by the aid of the Jesuit and the Inquisition, completely succeeded in killing free-thought. In France, where there was no Inquisition, her triumph was not so complete. She succeeded only in driving scepticism into disguise and subterfuge. The Commonwealth of Holland did France and the world in general the immense service of affording a printing house for free-thought which was on the confines of France, but beyond the reach of the French government. Descartes, without directly assailing the faith of the Church, planted in her face 542 the standard of thorough-going reason and entitled himself to a place in the Index. Growing sensuality and love of pleasure brought with them laxity of belief and impatience of priestly control. The authority of the clergy was impaired by their scandalous wealth and vice, which at the same time enhanced the odium of their persecuting tyranny. At last came Voltaire, Diderot, the *Encyclopædia*, and Rousseau. With literary cleverness unmatched and an incomparable genius for subtle attack, combined with a winning philanthropy, Voltaire converted and drew into the work of demolition, to them suicidal, the thrones of Louis XV., or rather of the Pompadour, of Catherine, and Frederick. The influence extended even to Spain, where Aranda, and to Portugal, where Pombal reigned. The Pope was constrained to dissolve the Order of Jesus. As Voltaire demolished in the name of Reason, Rousseau demolished in the name of Nature, taking an artificial society by storm. Helvétius went to the length of extreme materialism; but Voltaire, the master-spirit of the movement, remained a theist, and Rousseau was even for compulsory theism as the foundation of the state. The Revolution also, when it came, though violently and profanely anti-Christian, was in the main theist, and in the midst of the Terror held its Feast of the Supreme Being, with Robespierre for high priest. Atheism, in the persons of Chaumette and Anacharsis Clootz, went to the guillotine.

One hardly knows what to say about the *Last Will and Testament* of Jean Meslier, the priest who after thirty years’ service as a country curé bequeathed to his parishioners a profession of atheism. The work appears to have passed through the hands of Voltaire. It urges the arguments against natural theology in a very forcible as well as thorough-going way. But it seems, when it appeared, to have 543 made little impression and can be mentioned historically only as an indication of the masked ferment of the time.

England had a series of deists, Toland, Tindal, Collins, Chubb, and the rest, not men of much mark, though seekers of truth after their measure and in their day. The ecclesiastical polity of England was comparatively mild, and there was nothing to provoke indignant resistance to clerical tyranny like that which was provoked by the cases of Calas and LaBarre. Shaftesbury, a deist of a higher stamp, was, with his “moral taste,” a philosopher for men of taste, and could little stir the common world. In defence of orthodoxy came forth Bishop Butler, with a work which will be memorable forever as a model of earnest and solemn inquiry into the deepest questions, though its fundamental assumption is unwarrantable, since we should expect the difficulties of natural theology not to be reproduced but to be dispelled by revelation. Butler’s tone in discussion was an effective rebuke to those who had treated Christianity with levity as an obsolete interference with the pleasures of the world. His profound analysis of the moral nature of man in like manner rebuked the shallow and cynical theories which resolved everything into self-love; though here again his assumption of the authority of conscience as a divinely implanted monitor has by modern investigation been disallowed. Butler, however, with all his piety and his orthodox conclusions, must essentially be reckoned among rationalists. He frankly admits that the use of our reason is the only means we have of arriving at truth, never appealing from it to Church authority. He who recognizes reason as supreme must be deemed rationalist, let his own reason lead him or mislead him as it may. This is the vital line of cleavage which runs through the whole religious history and divides the religious world at the present day.

Butler had a popular shield-bearer in Paley, an extremely acute and effective though not profound 544 writer. Paley’s supposed proof of the existence of an intelligent Creator from the design visible in creation told greatly at the time and long continued to tell; though we now see that the universe, unlike the watch, presents terrible proofs of undesign as well as apparent proofs of design; not to mention that in the case of the universe, though adaptation is visible, the aim is not revealed. Paley's *Horae Paulinae*, however, is about the only piece of historical apologetics which has in any degree survived the destructive influence of modern criticism.

Warburton hardly calls for mention. In his *Divine Legation* he is right enough in saying that Moses did not teach the immortality of the soul; but the notion that the Mosaic dispensation must have had divine support because it could afford to dispense with that doctrine would now only provoke a smile.

Among literary apologists we can scarcely reckon Johnson. Yet he was a living defence, intellectual as well as moral, of his religion. That he speculated, we cannot doubt, and we know that he was not satisfied with the proofs of the immortality of the soul; but he suppressed doubt in himself and frowned it down in others. He was well justified in treating with contempt the posthumous works of Bolingbroke, which have not the slightest force or value beyond their literary form. Bolingbroke's scepticism, however, had a certain effect if it inspired Pope's *Universal Prayer*.

In Hume, on the other hand, we have the mightiest of all sceptics in the literal sense of the term, inasmuch as he was purely a doubter and seems hardly to have felt the desire of arriving at any positive result. He who has given rise to so much controversy was himself uncontroversial. His writings, considered as the vehicle of his opinions, are the perfection of literary art. Over common 545
minds the teacher who merely suspends judgment, seeming not to be in quest of positive truth, can never have much influence; but Hume had great influence over cultivated men of the world. His argument against the credibility of miracles, though it became as standard on one side as Paley's apologue of the watch upon the other, will hardly bear examination. Assuming the existence of God and His care for man as His work, which Hume does not openly deny, there is no presumption against His revelation of Himself in the only conceivable way, which is by an interruption of the general course of things; there is rather a presumption that He would so reveal Himself. Nor can it be maintained that no degree of evidence, say that of a multitude of scientific men, after providing all possible safeguards against deception, would satisfy us of the fact.

Gibbon's great work is instinct with the tendency of men of the world in the generation of Voltaire, Horace Walpole, and Hume. Its spirit is identical with that of Hume's philosophy and history. It is of first-rate importance in the religious controversy as having opened the trenches historically against revealed religion in undertaking to account for the success of Christianity by natural causes. But its cynical treatment of that which, on any hypothesis, was the prevailing and formative force is unphilosophical and detracts largely from the value of the work. He who could imagine that man had been happiest in the Roman Empire under the Antonines was an apt partisan of Lord North. Gibbon no doubt imagined himself a rich patrician of his golden era. Would he have liked to be a Roman slave? Conyers Middleton in his *Free Inquiry* into the ecclesiastical miracles glanced at the credibility of the Gospel miracles and had thus partly paved the way for Gibbon.

Among the disintegrating forces may be counted Unitarianism, which was growing among thinkers, and probably before very long became the mask for profounder scepticism in Protestant 546
Europe as it did afterwards in New England. We find it in England on the eve of the French Revolution, combined with science in Priestley and with mathematics and philosophy in Price.

Among the apologetic and defensive forces may be numbered the practical vindication of Christianity by a certain revival of piety in the Anglican Church which produced Wilberforce, Cowper, and the Evangelicals, and still more by the religious crusade of John Wesley. Wesley's achievements, however, were among the poor and illiterate, and were consequently demonstrations of the power of Christianity rather than of its truth. His Church had the advantage of being born, not like other Protestant Churches in doctrinal controversy, but in evangelical reaction against the impiety and vice of the age. It was, however, not undogmatic; besides what might be called the dogma of sudden conversion, it implicitly accepted not only the literal inspiration of Scripture, but the bulk of the Anglican Articles, to which was afterwards added, as an ordination test, general agreement with the more important of Wesley's sermons.

The French Revolution brought on a strong reaction against the free-thought which had been hideously travestied in the blasphemous follies, and sullied by the crimes, of the Jacobins. In England the Tory mob, with true instinct, sacked the library and laboratory of Priestley. Coleridge, who, like other young men of intellect, had hailed the revolutionary dawn, shared the reaction, and combining in a curious way German metaphysic with English orthodoxy and Establishmentarianism, produced a religious system which perhaps entitles him to high place among English theologians in the proper sense of that term, as denoting a philosophic inquirer into the nature of the Deity and the relations between the Deity and man; though, as his guiding light was philosophy, not authority or tradition, he 547 may in that respect be numbered among the promoters of free-thought and of the results to which it was ultimately to lead. Such free-thinking as there was naturally took a turn answering in violence to the repression. Tom Paine assailed orthodoxy, not with freedom only, but with enmity the most virulent. Though far from an attractive, he is by no means an unimportant figure. His criticisms of the credibility and morality of Scripture, unlearned and coarse as they were, went, not over the heads of the people like the high-flying and metaphysical speculations, but straight to their understandings and their hearts. It was difficult for apologetic fencers to parry such home thrusts. The same sort of effect has been produced by the irreverent frankness of Ingersoll in our own day. Shelley rushed from the religion of Eldon into what he took for Satanism; though his Satan is really the power of good, while the God of Eldon, as viewed by him, is the Devil.

Wrecked, body and soul, by the Thirty Years' war, and afterwards stifled under a group of petty despotisms, Germany was for a time lost to intellectual progress. Her churches and their clergy, the Lutheran clergy at least, were in a very low condition. When her intellect began to work again, it was in a recluse and highly speculative way, the natural consequence of its exclusion from politics and other fields of action, together with the complete severance of the academical element from the people. Hence, from Leibnitz and Lessing onward, there was a train of metaphysical philosophies, each of them professing to find in our consciousness a key to the mystery of Being and an account of God, of His counsels, and of the relation between Him and man. In derision of such speculations it was said that to the French belonged the land, to the English the sea, to the Germans the air. Essentially incapable of verification, these theories went on shifting in nebulous succession and, with the 548 exception of that of Kant, may now be said to have vanished, leaving scarce a rack behind. Even of the great Hegel little remains. Leibnitz, with his "best of all possible worlds," hardly survived *Candide*. Still, we must speak with respect and gratitude of these efforts of minds, powerful in their way and devoted to truth, to solve for us the great mystery. Speculation so free could not fail to promote general freedom of thought, and the treatment by these thinkers of the popular and established religion was as philosophic as possible, though, with the exception of Feuerbach, they were theists. By Lessing much was done for the recognition of all religions and the promotion of universal toleration.

Presently, however, came direct criticism of the Bible, the way to which, long before, had been lighted by Spinoza. It assumed a strange form in the work of Paulus, who applied to the Gospel miracles a solvent something like that which Euhemerus had applied to the Pagan Pantheon, reducing them to natural occurrences turned into miracles by a devout imagination. The miraculous fish with the coin in its mouth was a fish which would sell for the coin. The miraculous feeding of the five thousand was brought within the compass of belief by supposing that they were not fasting, but had only gone without a regular meal. Christ's walking on the water was his holding out a hand from the shore to Peter who had leaped into the water to ascertain whether it was really Christ that was walking on the shore.

Far more serious, and a startling blow to orthodoxy, was the *Life of Jesus*, by Strauss, who undertook to explain the Gospels on the mythical theory, showing that the reputed incidents of the life of Jesus and his miracles were mythical fulfilments of Old Testament prophecies and aspirations. From this, his first theory, Strauss afterwards partly receded, and in his second *Life of Jesus*, after a critical 549 examination of the authorities, he comes to the conclusion that "few great men have existed of whose history we have so unsatisfactory a knowledge as that we have of Jesus." The figure of Socrates, he thinks, though four hundred years older, is beyond all comparison more distinct. The momentous step, however, had been taken. Jesus had become the subject of a biography founded on critical examination of the materials, and Strauss is right in saying, as he does in his second *Life*, that when the biography was seriously taken up the doom of the theological conception was sealed. Lives of Christ, including even the most popular of them, however they may pretend and struggle to be orthodox, are really, as Strauss says, destructive of the theological conception, while they do not help to confirm our loyalty to historical truth. Ferdinand Christian Baur and his Tübingen school applied historical criticism to the early Christian Church, showing the conflict in it of the Pauline with the Petrine tendency, and bringing it altogether, as well as its source, within the pale of human history. Historical criticism of the Gospels was furthered by the progress of historical criticism in general, shown by such a work as Niebuhr's *History of Rome*. Wolf's treatment of the Homeric poems had already marked the birth of a critical spirit, which was aided by historical and archæological discoveries of all kinds, as well as by the growing influence of science on the methods of religious and anthropological speculation.

There was an evangelical reaction against rationalism in Germany with a train of controversialists and commentators reputed as orthodox. Yet even in these, more or less of a rationalist undertone is perceived. There is a tendency more or less apparent to minimize the supernatural, to throw the miracles into the background, and dwell rather on the spiritual significance of Christ's character and 550
words. This is very conspicuous in Neander, the head of the line. An orthodox English divine such as Mr. Rose might well, after a survey of German theology, make a rather mournful report.

In Holland, ever the land of free speculation, criticism advanced without fear, and at last by the pen of Kuenen arraigns the authenticity, antiquity, and authority of the historical books of the Old Testament to an extent totally subversive of their character as records of a primeval history, much more as organs of a divine revelation.

German philosophy had mingled with English theology through Coleridge. German criticism of the Bible did not lag much behind. Milman's *History of the Jews*, dealing with the subject in the spirit of an ordinary history, treating patriarchs as Arab sheiks and minimizing miracles, gave a serious shock to orthodox sentiment in England. Even what was deemed orthodox in Germany appeared rationalistic to the Anglican divines. To the evangelicals especially, whose leader was Simeon, and who occupied many of the fashionable pulpits, anything like critical treatment of the sacred history seemed impiety. Yet they, with their inward persuasion of conversion and spiritual union with the Saviour, as well as the Quaker with his inner light, or the Roman Catholic with his implicit faith in the Church, were really beyond the critic's reach.

A long line of British leaders of thought and controversialists succeeds. Rationalist and heterodox in different degrees were Thomas Arnold, Frederick Maurice, Stanley, Jowett, the writers of *Essays and Reviews*, and Robertson, of Brighton. Decidedly sceptical were Matthew Arnold, Carlyle, and James Anthony Froude. Reaction on the High Church side found leaders in Pusey, Newman, and Hurrell Froude. The evangelical pulpit combated at once rationalism and High Church. The state Church was awakened from its long torpor, and under the inspiration of its High Church party strove 551
to reanimate its Convocation.

Frederick Maurice impressed more by his character than by his writings, which were fatally obscure. He was rationalist enough to be deprived of his professorship in an Anglican college. At the same time he could persuade himself that subscription to the Thirty-nine Articles was no bondage but a security for free thought. To his yoke-fellow, Kingsley, is to be traced "muscular Christianity," a rather suspicious adaptation of the Sermon on the Mount to our times. But the pair exercised more influence as social missionaries, striving, in conjunction with Thomas Hughes, to give the labor movement a religious turn, than as religious philosophers or critics.

Thomas Arnold, the head-master of Rugby, was a man of noble character, powerful mind, and intense earnestness of purpose. He was a firm believer in Christianity as a revealed religion. But he held a most liberal view of the Church. He would have admitted to it all the sects of dissenters and have identified it as far as possible with the nation. His theory of the identity of the Church with the nation probably came to him from his passionate study of the ancient commonwealths. He forgot that the philosophers of Greece, though they might sacrifice a cock to Æsculapius, were really outside the state religion, and that the state religion made the chief of them drink hemlock. Prince of educators as he was, he sometimes laid too heavy a strain on his pupils, and prematurely developed their speculative tendencies. In the case of Clough especially, mental health and vigor seem to have been impaired by premature development.

With Thomas Arnold may be coupled his friend Whately, who, though, as Primate of the state Church of Ireland, he held the most equivocal of prelacies, was, by reason of his strong understanding, his fearless character, and his shrewd wit, essentially an iconoclast and a rebuker of ecclesiastical 552 pretensions, as well as a vigorous promoter of education. His keen sayings flew abroad, but his personal influence was greater than his influence as a divine. His *Historic Doubts* was an apologetic *jeu d'esprit* which told greatly in its day.

Bishop Connop Thirlwall was a man of first-rate power. At Cambridge he had set out as a rationalist, translating German theology of a heterodox cast and Niebuhr's *History of Rome*. But his intellect was curbed by a bishopric, and though he delivered liberal charges and personally exerted a liberal influence, he was lost to the direct service of reason.

Arthur Stanley was Arnold's best boy, his most devoted adherent, and his model biographer. He embraced Arnold's theory of the Church as coextensive with the nation and carried his theory of the supremacy of the state so far as to feel a certain sympathy with "Bluidie Mackenzie" as the defender of a state Church against the independence of the Covenanters of Scotland. His name was for a time a terror to all the orthodox, High Church or Low. Yet there was little that was terrible about him. The sweetness of his character was remarkable. His liberality of religious sentiment was boundless. But he had little of the logical or critical faculty, and showed scarcely the desire, still less the ability, to make his way to definite truth. His passion was history, and the historical picturesque was his forte. In a haze of this to the last he floated, coming to no determinate conclusion. His best works, apart from biography, are not his commentaries or sermons, but his lectures on the history of the Russian Church and his *Sinai and Palestine*; although we cannot help smiling when, in his *Sinai and Palestine*, we see him hunting with passionate interest and implicit faith for the imaginary scenes of mythical events.

Stanley's yoke-fellow, Jowett, was a man of a different cast of mind and of higher calibre, as all 553 the world now knows. But in him also, though from different causes, there was the same want of inclination to grasp or capacity for grasping definite truth. These two men were eminently typical of an age of religious dissolution, when people felt the ground of faith giving way under their feet and were striving, by some sort of compromise, to save themselves from falling into the abyss. That Jowett had drifted very far away, not only from orthodoxy, but from his belief in Christianity as a miraculous revelation, and even from belief in our knowledge of the historical character of Christ, the posthumous publication of his letters has plainly shown. How he could have reconciled it to his conscience to remain a clergyman, to hold the clerical headship of an Anglican college, to perform the service and administer the sacrament, it is not easy to see. We can only say that the position was found tenable by one of the most upright and disinterested of mankind. Jowett's defence probably was and is the defence of others, and the indication of spreading doubt. Clergymen are educated men and can hardly be proof against that which is carrying conviction to other minds.

Robertson, of Brighton, as an eloquent preacher and spiritual leader, rather on the rationalist side, is not to be forgotten. In his sermons there is an evident tendency to liberalize Christianity and to present it ethically as a religion of purity and love rather than as a miraculous revelation which did not escape the keen scent of alarmed orthodoxy and exposed the preacher to some social persecution.

By this time a strong current in an opposite direction had begun to flow. The religious movement was closely connected with the political movement, especially where there was a state Church. Alarmed by the progress of liberalism, which had carried the Parliamentary Reform bill and threatened 554 to withdraw from the Church of England the support of the state, some of the clergy began to look about for a new foundation of their authority, and thought that they found it in apostolical succession and the sacerdotal theory of the sacraments. The leaders of the movement were Pusey, professor of Hebrew at Oxford; Henry Newman, a Fellow of Oriel College; and, in its opening, Hurrell Froude, in whose *Life of Becket* its spirit and aims are plainly revealed. It took practically the shape of an attempt to return to the priestly Middle Ages. Oxford, with its mediæval colleges, the Fellows of which were then clerical and celibate, formed the natural scene of such an attempt. Pusey, who, by his academical

rank, gave his name to the movement, was a man of monastic character and mind, with a piety intense but austere and gloomy enough almost to cling to such a doctrine as the irremissibility of post-baptismal sin. Henry Newman was a man of genius, a writer with a most charming and persuasive style, great personal fascination, and extraordinary subtlety of mind. What he lacked was the love of truth; system, not truth, was his aspiration; and as a reasoner he was extremely sophistical, however honest he might be as a man. In this respect he presented a singular contrast to his brother, Francis Newman, in whom the love of truth was the ruling passion, intense and uncompromising, while he was totally devoid of the gifts of imagination with which Henry was endowed. Henry Newman's attempt to revive mediæval doctrines presently landed him, with his immediate following, in the mediæval Church. Pusey was illogical enough to refuse the leap. He was also believed to be rather strongly attached to the leadership and spiritual directorship which, as a magnate of the Church of England, he enjoyed. He went so near to the brink as, in his *Irenicon*, to avow that nothing separated him from 555
Rome but the unmeasured autocracy of the Pope and the excessive worship of the Virgin, both of them mere questions of degree. Manning in time followed: an aspiring hierarch who would probably have stayed in the Church of England if they had made him a bishop. Passing into the Church of Rome, he became a Cardinal, an active intriguer of the Vatican, and an extreme Ultramontane, outvying Newman, who, when the convert's first ecstasy was over, might be said to be converted rather than changed.

The mediævalizing movement owed much to the fascinations of mediæval art. The Gothic churches and cathedrals and the Gothic ruins of abbeys have been very powerful conservators and propagators of the faith of their builders. It is curious that this talisman should have been renounced by the Church of Rome in favor of the heathen style, of which St. Peter's is the paragon, magnificent but, in a religious sense, unimpressive.

By the progress of Tractarianism British Protestantism was alarmed and incensed. The Oxford Convocation was the scene of a pitched battle brought on by a bold deliverance of Ward, a disciple of Newman, more logical and daring than his master, who exultingly proclaimed that English clergymen were embracing "the whole cycle of Roman doctrine." Ward, after a struggle which was a sort of Armageddon of High and Low Church, was condemned and deprived of his degree. Newman's conversion speedily followed. The rationalists, such as Stanley and Jowett, voted on liberal grounds against the condemnation of Ward.

A storm from the other quarter was raised by *Essays and Reviews*, a collection of seven essays written by clergymen of the rationalistic school, having for its object the liberalizing of inquiry in the Church. The manifesto at the time created an immense sensation, though in the present advanced state of doctrinal disintegration it would almost pass unnoticed. One of the essays, the most innocent, it is 556
true, which nevertheless committed the author to the general object of the combination, was written by the present Archbishop of Canterbury, and caused the High Church clergy to protest against his appointment as a bishop. The glove thus thrown down was taken up by the High Churchmen. The writers were arraigned for heresy before the Privy Council, and, as Carlyle said, you had a bench of old British judges, "like Roman augurs, debating with iron gravity questions of prevenient grace, supervenient moonshine, and the color of the bishop's nightmare if that happened to turn up." Before the same tribunal was arraigned Colenso, a missionary bishop of South Africa and an eminent mathematician, whose arithmetical instincts had led him to examine the numerical statements of the Pentateuch, with highly heretical results. Both the essayists and Bishop Colenso escaped conviction. The Committee of Privy Council, if it was judicial, was also political, and it was resolved, if possible, to avert a rupture in the state Church. Veteran lawyers had little difficulty in finding grounds for acquittal when they did not choose to convict. The language of the impugned writings was seldom so precise as to defy the power of interpretation. "Either the passage means what I say, or it has no meaning," thundered the counsel for the prosecution. "Is it not possible, Mr. Blank, that the passage may have no meaning?" was the reply of the judge. The Rev. Mr. Voysey, however, succeeded in obtaining the honor of a conviction. Tendered a week to retract, he thanked the court for the opportunity they had given him of rejecting the offer of repurchasing his once cherished position in the Established Church by proclaiming himself a hypocrite.

Hampden, Regius Professor of Theology at Oxford, formed another object of High Church attack. He had been condemned by the university on account of doctrines alleged to be anti-Trinitarian, and 557
his appointment by a Whig ministry to a bishopric caused a renewal of the onslaught, which, however, only served by its failure to emphasize the fact that the Church of England was in complete subjection to the state. In this, as in the general commotion, prominently figured Wilberforce, Bishop of Oxford, son of the great evangelical and philanthropist, a man gifted, dexterous, and versatile, who would have made a first-rate advocate or politician, balancing himself with one foot on his hereditary Evangelicism, the other on High Churchmanship, to which, in his heart, as a hierarch, he inclined. A character so ambiguous could make little impression, however great his abilities might be.

James Anthony Froude had been a follower and fellow-worker of Newman. But on Newman's secession he not only hung back, but violently recoiled and produced a highly sceptical work, *The Nemesis of Faith*, which entailed his resignation of a clerical fellowship in an Oxford college. Then he exemplified the strange variations of the age by coming out as an historian in the colors of Carlyle.

Carlyle himself is not to be left out of sight in an account of the progress of religious thought; for his Scotch Calvinism, transmuted into hero worship, has taken a strong hold, if not on the distinct convictions, on the sentiment and temper of the nation. If he has administered wholesome rebuke to the self-complacency of democracy with its ballot-box, he has also set up a worship of force and kindled a spirit of violence totally subversive of the Sermon on the Mount.

Matthew Arnold, with his silver shafts, was rather a connoisseur in all lines than a serious philosopher or theologian; but he also, with his conversion of God into the "not ourselves which makes for righteousness," did something in his light but insinuating and charming way to forward 558
disintegration.

But in 1874–77 appeared *Supernatural Religion*, a searching and uncompromising inquiry into the historical evidences of supernatural Christianity. The book, though attacked on secondary points with perhaps superior learning by Bishop Lightfoot, Bishop Westcott, and others, cannot be said to have met with any general answer. Supplemented in some respects by Dr. Martineau's *Seat of Authority in Religion* and other works on the same side, it sets forth the sceptic's case against the supernatural.

Miracles, says criticism, belong to an age of ignorance. With the dawn of knowledge they diminish. In its meridian light they disappear. The Jews were eminently addicted to belief in miracles. There was Satanic miracle as well as divine; nor can any distinction be drawn as a matter of evidence between the two. As little can any distinction be drawn in point of evidence between the Gospel miracles and the ecclesiastical miracles, which nevertheless Protestants reject. The miracles of one sort, the demoniac, are bound up with the Jewish belief in possession by personal devils, from which all efforts to disentangle them so as to resolve them into cures of lunacy by moral influence are vain. The four Gospels and the Acts, which comprise the historic evidences, are all anonymous, all of uncertain authorship. The first three Gospels are evident incrustations upon an older document which is lost and about which nothing is known. In not one of the five cases can the existence of the book be traced to the time of the events or a time so near the events as to preclude the growth of fable in a highly superstitious and totally uncritical age. The presentation of Christ's character and teaching in the fourth Gospel, which is Alexandrian, is far from identical with the presentation in the first three Gospels, which are Jewish. There are irreconcilable discrepancies between the Gospels as to matters of 559
fact, notably in regard to the genealogy of Christ, the length of his mission, the Last Supper, the day of the Crucifixion, the details of the Resurrection and the Ascension. Such miracles as the miraculous darkness, the earthquake, the rending of the veil of the Temple, the opening of the tombs and the apparition of the dead in the streets of Jerusalem, being totally unconfirmed by history or by any recorded effect, stagger belief. Such testimony as St. Paul bears to the Resurrection is second hand, is that of a convert in the ecstasy of conversion, and is manifestly uncritical. His own enthusiasm is intelligible on merely human grounds. We may be sure that had God become incarnate to save man, absolutely conclusive proof of that fact would have been vouchsafed. But the proof is not sufficient to establish anything not otherwise perfectly credible, far less to establish the miraculous Birth, the Resurrection, and the Incarnation. Such in broad outline is the case of Rationalism against Supernatural Religion presented by the work just mentioned and its allies. The effects are visible even

in High Church writings. In the writings of liberals, of course, they are still more visible. Jowett had come to the conclusion that our sources of knowledge about Christ had been reduced to a single document, no longer in existence, which formed the basis of the first three Gospels.

The desire to minimize the supernatural and throw it into the background, bringing the personal character of Christ and his ethical teaching into the foreground, is now manifest in English, as it has long been in German, divines. It is conspicuous in the very popular and colorably orthodox works of Dr. Farrar. In his *Life of Lives* the supernatural has little place. There is an evident tendency throughout to disentangle from it the character and moral teaching. Responsibility for belief in the Godhead of 560
Christ seems to rest on the Nicene Council. In the *Life of Christ* we see reduced to a natural occurrence the miracle of Gadara, where the devils cast out of the men enter into the herd of swine. It is needless to say that with the miraculous element of these occurrences their value as evidence for the supernatural disappears.

Scotland generally remained fast bound by her Westminster Confession. There had been a period of liberalism marked by the appearance of "Jupiter" Carlyle; Robertson, the historian; Dugald Stewart, and other philosophers and men of mind. But the Church of Scotland being democratic, its faith was in the keeping of the people, who were impervious to criticism and naturally opposed to innovation. At last, however, the thaw came, hastened perhaps by the collision between the state Church of Scotland and the Free Church. The Westminster Confession, it seems, has now been tacitly laid aside, and Scotch theology has had its Robertson Smith, whose critical views on the Old Testament earned him removal from his professorial chair.

Another book which in its day startled the world and awakened all the echoes of orthodox alarm was Buckle's *History of Civilization*, in which the characters of nations and the progress of humanity were traced to physical influences, excluding the moral and by implication the theistic element. Its thesis was supported by an overwhelming display of learning. Though not expressly, it was in its tenor hostile to religious belief. Of Buckle's work less is now heard, but it had an influence in its day, perhaps more in America than in its native land. Americans, it seems, were captured both by the boldness of the theory and by the imposing display of erudition.

In the line of learned and dispassionate research France has produced Renan, whose *Life of Jesus*
especially made a vast impression on Europe, and still probably exercises an influence by virtue not 561
only of the boldness of the speculation and the intense interest of the subject, but of the extreme beauty of the style. The work, however, is one in which imagination acts strongly on history. It lacks critical basis; not that the author fails fully to set out his authorities, but that in his narrative he fails to discriminate among them. One incident is treated as real, another as mythical, to suit the requirements of poetical conception, without reason assigned for the distinction. There seems no reason, for example, why the miracle of the raising of Lazarus should be treated as historical, though in the sense of imposture or illusion, while other miracles are treated as totally unhistoric. Nor is the portrait free from a French and slightly sensuous cast. From the whole body of Renan's histories of Israel, of Christ, and of the early Church the supernatural is entirely excluded.

The Roman Catholic Church has not suffered from criticism—historical, literary, or scientific—in the same way as the Protestant Churches, that is, internally, because it depends not so much on intellectual conviction as on ecclesiastical organization, and rests comparatively little on the authority of the Bible. Its priesthood has not been affected like the clergy of the Church of England or the ministries of the Protestant Churches. But it has everywhere been losing the educated classes, or retained a part of them, not so much from conviction—still less from speculative conviction—as because its alliance is congenial to political and social reaction. Its inability to come to terms with science has been shown by the recent case of St. George Mivart, and scientific eminence among Roman Catholics is rare. In Italy, the centre of the system, while the poorer classes still flock to the liquefaction of the blood of St. Januarius at Naples or the exudation of the bones of St. Andrew at
Amalfi, still climb the Holy Staircase on their knees or make pilgrimages to the House of Loretto, the 562
general tone of intelligence is described as sceptical, though aristocratic families, more especially those of Papal creation, adhere to the Papacy on political and social rather than on religious grounds. Near to the shrine of Ignatius Loyola stands the statue of Giordano Bruno, on the spot of his

martyrdom by fire, “dedicated to him by the age which he foresaw.” Attempts have been made to liberalize the Church of Rome and enable it to float with the current of the day, but they have failed. Pio Nono for a time put himself at the head of the popular and liberal movement in Italy. But he soon found, as Carlyle said, that it was an alarming undertaking. Lamennais’s attempt at liberalization ended, after a long intellectual agony, in his own secession. The combined attempt of Lacordaire to liberalize ecclesiastically, and of Montalembert to liberalize politically, had a scarcely less melancholy result; both of them died under the shadow of Papal displeasure or of that of the Jesuit party, by which the Papacy was controlled. The defiantly reactionary spirit of Ultramontanism de Maistre has prevailed. The Jesuit has ruled at the Vatican. Under his guidance the Papacy has proclaimed the infallibility of the Pope and the Immaculate Conception of the Virgin, thus breaking completely and finally with reason and with all who, like the “Old Catholics” in Germany, remained in some degree within that pale. It has gained in its own despite in respectability and influence by deprivation of its temporal power, against which the Prisoner of the Vatican still hopelessly protests.

In France the national religion, abolished and persecuted by the Jacobins, was restored for a political purpose by Napoleon. The new Charlemagne was requited with the degradation of the Pope, who came to Paris to crown him on the morrow of the murder of the Duc d’Enghien and broke the best traditions of the Holy See by failing to veto the divorce from Josephine. Identified with political 563
reaction under the restored Bourbons, the Church nearly suffered wreck in the revolution by which they were overthrown. She remained the object of intense and persecuting hatred to the revolutionary and republican party. Plaintively, when the Orleans monarchy fell, she chanted *Domine salvum fac populum*. Joyously, when the Empire succeeded, she chanted *Domine salvum fac Imperatorem*. But the Empire in its turn fell. The Church has continued to ally herself with political reaction and aristocratic hostility to the Republic, though she has latterly been receiving hints from the Vatican that the Republic is strong, that the monarchical and imperial pretenders both are weak. The consequence is a violence of hostility on the part of the Radicals and Socialists which assails not only monastic fraternities, but educational institutions and even charitable institutions in clerical hands, and has produced an infidel literature carrying blasphemy to the height almost of frenzy and culminating in a comic *Life of Christ*. The official world of France is almost formally infidel, and a religious expression would be very injurious to a politician. On the other hand, the Church braves and exasperates public reason with apparitions of the Virgin and the miracles of Lourdes. Over most of the women, the priest still holds sway. Of the men, not many are seen in churches. The general attitude of the educated towards religion seems to be not so much that of hostility as that of total indifference, a state of estrangement more hopeless than hostility itself.

There is in France a Protestant Church, of which Guizot was an eminent member, and which in his time was renewing its life. But there was a schism in it between an evangelical party and a party which was entirely rationalist, Guizot belonging to the first, his son-in-law to the second; and rationalism seems to have prevailed. With the Protestant party of France was allied an evangelical party in 564
Switzerland, of which Vinet was the most eloquent divine. But in Vinet, as in liberal divines generally, we find an inclination to rest on the spiritual rather than on the supernatural. In the city of Calvin generally opinions appear to reign more opposed to the religion of Calvin than those for which he burned Servetus.

But of the disintegrating forces criticism—the Higher Criticism as it is the fashion to call it—has by no means been the only one. Another, and perhaps in recent times the more powerful, has been science, from which Voltaire and the earlier sceptics received little or no assistance in their attacks; for they were unable to meet even the supposed testimony of fossils to the Flood. It is curious that the bearing of the Newtonian astronomy on the Biblical cosmography should not have been before perceived; most curious that it should have escaped Newton himself. His system plainly contravened the idea which made the earth the centre of the universe, with heaven above and hell below it, and by which the cosmography alike of the Old and the New Testament is pervaded. Yet the Star of Bethlehem remained little disturbed as an article of faith. The first destructive blow from the region of science was perhaps dealt by geology, which showed that the earth had been gradually formed, not suddenly created, that its antiquity immeasurably transcended the orthodox chronology, and that death had come into the world long before man. Geologists, scared by the echoes of their own teaching,

were fain to shelter themselves under allegorical interpretations of Genesis totally foreign to the intentions of the writer; making out the "days" of Creation to be æons, a version which, even if accepted, would not have accounted for the entrance of death into the world before the creation of man. Those who attended the lectures of Buckland and other geologists of that generation well 565
recollect the shifts to which science had recourse in its efforts to avoid collision with the cosmogony supposed to have been dictated by the Creator to the reputed author of the Pentateuch. That the narrative of Genesis could hold its ground so long against science was due at once to its dignity, which earned for it the praise of Longinus, and to its approximation to scientific truth in describing the universe as the work of a single mind. These characteristics have even in the day of geology and Darwin raised up for it such an apologist as Mr. Gladstone, whose defence, however, amounts to this, that the Creator, in giving an account of his own work to Moses, came remarkably near the truth.

The grand catastrophe, however, was the discovery of Darwin. This assailed the belief that man was a distinct creation, apart from all other animals, with an immortal soul specially breathed into him by the author of his being. It showed that he had been developed by a natural process out of lower forms of life. It showed that instead of a fall of man there had been a gradual rise, thus cutting away the ground of the Redemption and the Incarnation, the fundamental doctrines of the orthodox creed. For the hypothesis of creation generally was substituted that of evolution by some unknown but natural force.

Not only to revealed or supernatural but to natural religion a heavy blow was dealt by the disclosure of wasted æons and abortive species which seem to preclude the idea of an intelligent and omnipotent designer.

The chief interpreters of science in its bearing on religion were, in England, Tyndall and Huxley. Tyndall always declared himself a materialist, though no one could less deserve the name if it implied anything like grossness or disregard of the higher sentiments. He startled the world by his declaration that matter contained the potentiality of all life, an assertion which, though it has been found difficult 566
to prove experimentally, there can be less difficulty in accepting, since we see life in rudimentary forms and in different stages of development. Huxley wielded a trenchant pen and was an uncompromising servant of truth. A bitter controversy between him and Owen arose out of Owen's tendency to compromise. He came at one time to the extreme conclusion that man was an automaton, which would have settled all religious and moral questions out of hand; but in this he seemed afterwards to feel that he had gone too far. An automaton automatically reflecting on its automatic character is a being which seems to defy conception. The connection of action with motive, of motive with character and circumstance, is what nobody doubts; but the precise nature of the connection, as it is not subject, like a physical connection, to our inspection, defies scrutiny, and our consciousness, which is our only informant, tells us that our agency in some qualified sense is free.

Materialists or physicists such as Tyndall and Huxley, or their counterparts on the Continent, would console us for the loss of religion by substituting the majesty of law. But the idea of law implies a law-giver or an intelligent and authoritative imponent of some kind. There is no majesty in a mere sequence, even the most invariable and on the largest scale, the existence of which alone physical science can prove.

The all-embracing philosophy of Mr. Herbert Spencer excludes not only the supernatural but theism in its ordinary form. Yet theism in a subtle form may be thought to lurk in it. "By continually seeking," he says, "to know, and being continually thrown back with a deepened conviction of the impossibility of knowing, we may keep alive the consciousness that it is alike our highest wisdom and our highest duty to regard that through which all things exist as the Unknowable." In this and 567
subsequent passages he evidently looks upon the Unknowable as an object of reverence, otherwise it would hardly be our highest duty to regard it as that through which all things exist, or to maintain any particular attitude towards it. But Unknowableness in itself excites no reverence, even though it be supposed infinite and eternal. Nothing excites our reverence but a person, or at least a Moral Being. There lingers in Mr. Spencer's mind the belief that the present limit of our knowledge is the veil of the Deity.

Had the Darwinian discoveries been known to Schopenhauer they would have conspired with the earlier discoveries of science and with his pitiless survey of the human lot to confirm him in the belief that this was the worst of all possible worlds. Amid the general distraction even pessimism has found adherents, and a European version of Buddhism promising final relief from the miseries of conscious existence has been accepted as an anodyne by troubled minds.

Positivism, the work of Comte, totally discards belief in God and treats theism in all its forms as merely a mode of contemplating phenomena and a step in the course of human progress. Yet the Positivist feels the need of a religion, and for the worship of God he substitutes the worship of Humanity. Humanity is an abstraction and an imperfect abstraction, the course of the human race having not yet been run. It cannot hear prayer or respond in any way to adoration. The adherents of Comte's religion, therefore, are few, though those of his philosophy are more numerous, and the religious Comtists appear to be rather enthusiasts of Humanity than worshippers of the abstraction.

A conspicuous though equivocal place among the defenders of revealed religion in England was
held by Mansel, professor of moral and metaphysical philosophy at Oxford and afterwards dean of St. 568
Paul's. Attempting in his Bampton lectures to make philosophy fall on its own sword, he fell on his own sword in the attempt. He maintained that God, being absolute, could not be apprehended by the finite intelligence of man, and that the finite morality of man was not the same as the absolute morality of God. Hence the passages of the Bible which seemed to conflict with human morality really transcended it and were moral miracles. In this Mansel was reviving the theory of Archbishop King and Bishop Browne, who had maintained that our knowledge of God was not actual, but merely analogous. The inference was promptly drawn by Mansel's opponents that what could not be apprehended could not be matter of belief, and that he had therefore cut away the possibility of belief in God. They even contended that he was too anti-theistic, since he did away with all possibility of reverence for the Unknown. To deny the identity of human with divine morality and assert that what was immoral with man was moral with God was to sever the moral relation between God and man, and, in effect, to destroy morality altogether. We could conceive of only one morality, and acts ascribed to God which violated that morality must be to us immoral. "If," said John Stuart Mill in the fervor of ethical protest, "an Almighty Being tells me that I shall call that righteous which is wicked or go to hell, to hell I will go."

To meet the inroads of science on Biblical cosmogony and cosmography recourse was had to allegorical interpretation. But allegorical interpretation cannot be forced upon a writer when it manifestly is not in his mind. The writer or writers of Genesis undeniably intended his or their statements to be taken literally. They meant that the earth was really created in six days, as the Fourth Commandment assumes; that the formation of Eve out of a rib of Adam, the temptation of Eve by the
serpent, and all the actions of the anthropomorphic God, who walks in the garden at evening and 569
makes garments for Adam and Eve, were actual events. To foist upon them allegorical interpretation is to falsify their testimony. Besides, instead of having the facts of the creation revealed to us we are left to interpret allegory at a venture.

Recourse has been had to the theory of partial inspiration, admitting historical and even moral errors in Scripture, but setting them down to the human element in the composition, which has to be recognized without prejudice to that element which remains divine. Such a collaboration of infallibility with fallibility, both historical and moral, is a desperate hypothesis, especially when the object was to reveal vital truths to man. Nor could man distinguish the human element from the divine without being himself inspired and thus above the need of revelation. A condescension of the divine to the primitive shortcomings and aberrations of humanity is a solution surely opposed to any conceivable purpose of revelation.

Another line of defence has been the hypothesis, which may be called quasi-inspiration, reducing the inspiration of the Scriptures to a supreme degree of the same sort of inspiration which we recognize in a great poet or a great author of any kind. This is mere playing with the term "inspiration," and little better than an equivoque. It may be, and we hope it is, true that the Author of our being manifests Himself in whatever is morally grand and elevating. But this belief is very different from a belief in the special inspiration of the Bible.

Evolution, again, which at first was repelled as atheistic, is now adopted by some as the key to revelation and the solution of all difficulties connected with it. This would make God in His revelation of Himself to man, without apparent motive, subject Himself to a physical or quasi-physical law, the knowledge of which has been withheld from man till the present time. An imperfect revelation of the 570 divine character, one for example which should exhibit the justice of God without His mercy, would be a deception of man instead of a revelation. Besides, evolution repels finality, and we could have no assurance that the manifestation of the divine nature in Christ and the Gospel would be final.

It is needless to say how manifestly all these theories have their origin in controversial necessity, how totally alien they are to the view taken hitherto by the Christian Churches of the Scriptures, and how unlikely it is that God, in revealing Himself to man for the purpose of human salvation, should have chosen a method such as would entail inevitable misconstruction for many centuries and postpone the true interpretation of His character and dealings to an age of human criticism and science.

The ethics of Christianity have hitherto comparatively escaped systematic criticism and are still generally and officially professed. An appeal to the principles of the Sermon on the Mount continues to command formal respect. But Christ's view of this world as evil and his renunciation of it for the Kingdom of God have been practically laid aside by all but specially religious men. Christ's moral code was, in its direct bearing, only personal or social, politics and commerce not having come within the view of the teacher of Galilee. In regard to public and international concerns, the abjuration of his principles is most striking. In that sphere Christian meekness, mercy, and self-sacrifice are being openly superseded by maxims drawn from the Darwinian Struggle for Existence and by avowals of the right of the strong. Even professed ministers of Christ have been pandering to Imperialism and the lust of war. In truth, by a strange turn of events, Christian ethics, in questions between nation and nation and in questions concerning humanity at large, have been passing out of the hands of the orthodox 571 teachers of supernatural Christianity into those of men who recognize only the human character and ethical teachings of life.

Professor Seeley in his earlier days had made a great impression with his *Ecce Homo*, an attempt to bring the character of Christ nearer to the heart of humanity. The work was decidedly pietist; yet a rationalizing tendency was scented in it by the Evangelicals, whose leader, Lord Shaftesbury, denounced it. Its author promised a theology. But when, after years of reflection and subjection to the influences of a moving time, the theology came, under the title of *Natural Religion*, it was a total disappointment. Religion was reduced by it to enthusiasm, not exclusively Christian or even theistic, but of any kind, such as enthusiastic love of country or of art.

Minds of the finer cast have preserved the religious spirit, while they have thrown off the shackles of creed and even regarded the whole religious question as matter of doubt and suspense.

"There lives more faith in honest doubt,
Believe me, than in half the creeds."

This is the pervading spirit of Tennyson's poems, and of such a work as Amiel's diary, but it must manifestly be confined to a circle of minds such as those of Tennyson and Amiel. Agnosticism is the condition into which a large number of educated minds have been more or less consciously passing or drifting. But while in some of them a religious spirit still prevails and the hope is cherished of a new religious dawn, others seem to have finally settled in the conviction that theological inquiry is hopeless and that our knowledge must forever be bounded by that which our senses and science tell us about the laws or forces of our own world.

Reluctance to give up belief in the unseen world and perhaps still more unwillingness to think that 572 the loved ones who are lost by death are lost forever have given birth to Spiritualism. It will hardly be thought necessary to comment on an illusion which has been so often and so decisively exposed. Its very name is belied when the spirits have to materialize before they can make their existence known or hold converse with those who evoke them. The alleged communications from the spirit world through such a medium as Planchette have been trivial, almost fatuous. It is now forgotten that the movement began with table-turning, as though spirits had a special affinity for tables.

Among the anti-theistic, or at least the anti-ecclesiastical, influences and the solvents of our religious system may be reckoned the foundation of systems of morality independent of the divine sanction. Paley's definition of virtue is "the doing good to mankind in obedience to the will of God and for the sake of everlasting happiness." This is the theistic view. Opposed to it is the Utilitarian system, generally connected with Bentham's name, which finds the sole and sufficient motive and reward of virtue in the promotion of our well-being here. So long as a system aims at perfection and beauty of character which transcend temporal happiness there is in the philosophy a theistic element, patent or latent. But of perfection and beauty of character the Utilitarian philosophy in its thorough-going form takes no account.

The weakening of religious belief as a social influence on the conservative side is very marked and excites the fears of statesmen, some of whom, even if they are Protestants, are inclined to look with complacency on the Papacy as a bulwark against social revolution. The drudge rested in dull contentment with his lot while he could believe that hereafter the parts of Dives and Lazarus would be reversed and full amends would be made to him for his privations in this life. This hope having vanished, he is resolved, if he can, to have a share of the good things of the present world. That this 573
sentiment helps to set seething the caldron of socialistic and communistic agitation, all who are familiar with labor literature must be aware. It would probably be found that anarchism and atheism generally went together.

As the natural consequence of the loosened hold of religion over the nations, there has been a general tendency in Europe towards disestablishment. In Italy, the seat of the Papacy, disestablishment is complete. In Spain, while Catholicism is still recognized as the exclusive religion of the nation, the immense revenues of the clergy have been secularized, monasteries have been dissolved, and religion has been almost reduced to a department of the state. In France the process has gone still further than in Spain, and religion may almost be said to be not only a department, but a despised department, of the state. In Ireland the state Church has been disestablished. A bill has been brought in for the disestablishment of the Church in Wales, and in England disestablishment seems to be approaching, its advent being hastened by the collision of ritualism with the anti-Roman and anti-sacerdotal spirit of the nation. Popular education has everywhere been largely secularized, and that process is still going on. Sunday-schools or other secondary influences can scarcely countervail the general banishment of religion from the training of the child.

Religion passed from old to New England in the form of a refugee Protestantism of the most intensely Biblical and the most austere kind. It had, notably in Connecticut, a code of moral and social law which, if fully carried into effect, must have fearfully darkened life. It produced in Jonathan Edwards the philosopher of Calvinism, from the meshes of whose predestinarian logic it has been found difficult to escape, though all such reasonings are practically rebutted by our indefeasible consciousness of freedom of choice and of responsibility as attendant thereon. New England 574
Puritanism was intolerant, even persecuting; but the religious founder and prophet of Rhode Island proclaimed the principles of perfect toleration and of the entire separation of the Church from the state. The ice of New England Puritanism was gradually thawed by commerce, non-Puritan immigration from the old country, and social influences, as much as by the force of intellectual emancipation; though in founding universities and schools it had in fact prepared for its own ultimate subversion. Unitarianism was a half-way house through which Massachusetts passed into thorough-going liberalism such as we find in Emerson, Thoreau, and the circle of Brook Farm; and afterwards into the iconoclasm of Ingersoll. The only Protestant Church of much importance to which the New World has given birth is the Universalist, a natural offspring of democratic humanity revolting against the belief in eternal fire. Enthusiasm unilluminated may still hold its camp-meetings and sing "Rock of Ages" in the grove under the stars.

The main support of orthodox Protestantism in the United States now is an off-shoot from the old country. It is Methodism, which, by the perfection of its organization, combining strong ministerial authority with a democratic participation of all members in the active service of the Church, has so far not only held its own but enlarged its borders and increased its power; its power, perhaps, rather than its spiritual influence, for the time comes when the fire of enthusiasm grows cold and class meetings lose their fervor. The membership is mostly drawn from a class little exposed to the disturbing influences of criticism or science; nor has the education of the ministers hitherto been generally such as to bring them into contact with the arguments of the sceptic.

The character and intensity of the movement in Europe have been greatly influenced by the 575
existence of state Churches and the degrees of obnoxious privilege which the state Churches severally have possessed. Where the yoke of the establishment was heavy, as in France under the Bourbons, free-thought has been lashed into fury; where, as in England, the ecclesiastical polity has been comparatively mild, it has taken the gentler form of evangelical dissent. In the United States at the beginning of the last century there were faint relics of state Churches, Churches, that is, recognized and protected, though not endowed, by the state. But there has been little to irritate scepticism or provoke it to violence of any kind, and the transition has accordingly been tranquil. Speculation, however, has now arrived at a point at which its results in the minds of the more inquiring clergy come into collision with the dogmatic creeds of their Churches and their ordination tests. Especially does awakened conscience rebel against the ironclad Calvinism of the Westminster Confession. Hence attempts, hitherto baffled, to revise the creeds; hence heresy trials, scandalous and ineffective.

Who can undertake to say how far religion now influences the inner life of the American people? Outwardly life in the United States, in the Eastern States at least, is still religious. Churches are well maintained, congregations are full, offertories are liberal. It is still respectable to be a church-goer. Anglicanism, partly from its connection with the English hierarchy, is fashionable among the wealthy in cities. We note, however, that in all pulpits there is a tendency to glide from the spiritual into the social, if not into the material; to edge away from the pessimistic view of the present world with which the Gospels are instinct; to attend less exclusively to our future, and more to our present state. Social reunions, picnics, and side-shows are growing in importance as parts of the Church system. Jonathan 576
Edwards, if he could now come among his people, would hardly find himself at home.

The Catholic Church had come out to America in evil companionship with Spanish conquest. Together with the Spanish colonies she decayed, and her history during the past century in South America appears to have been that of a miserable decline which could add nothing to religious thought or history. Mexican liberalism, under the presidency of Juarez, cast off allegiance to her, and a priest dared not show himself in the dress of his order on the street. In French Canada the Catholic Church has reigned over a simple peasantry, her own from the beginning, thoroughly submissive to the priesthood, willing to give freely of its little store for the building of churches which tower over the hamlet, and sufficiently firm in its faith to throng to the fane of St. Anne Beaupré for miracles of healing. She has kept the *habitant* ignorant and unprogressive, but made him, after her rule, moral, insisting on early marriage, on remarriage, controlling his habits and amusements with an almost Puritan strictness. Probably French Canada has been as good and as happy as anything the Catholic Church had to show. The priesthood was of the Gallican school. It lived on good terms with the state, though in French Canada the state was a conqueror. From fear of New England Puritanism it had kept its people loyal to Great Britain during the Revolutionary war. From fear of French atheism it kept its people loyal to Great Britain during the war with France. It sang *Te Deum* for Trafalgar. So things were till the other day. But then came the Jesuit. He got back, from the subserviency of the Canadian politicians, the lands which he had lost after the conquest and the suppression of his Order. He supplanted the Gallicans, captured the hierarchy and prevailed over the great Sulpician Monastery in a 577
struggle for the pastorate of Montreal. Other influences have of late been working for change in a direction neither Gallican nor Jesuit. Railroads have broken into the rural seclusion which favored the ascendency of the priest. Popular education has made some way. Newspapers have increased in number and are more read. The peasant has been growing restive under the burden of tithe and *fabrique*. Many of the *habitants* go into the Northern States of the Union for work, and return to their own country bringing with them republican ideas. Americans who have been shunning continental union from dread of French-Canadian popery may lay aside their fears.

It was a critical moment for the Catholic Church when she undertook to extend her domain to the American Republic. She had there to encounter a genius radically opposed to her own. The remnant of Catholic Maryland could do little to help her on her landing. But she came in force with the flood of

Irish, and afterwards of South German, emigration. How far she has been successful in holding these her lieges would be a question difficult to decide, as it would involve a rather impalpable distinction between formal membership and zealous attachment. That she loses the zealous attachment of a great part of them in two or three generations, and that of the South Germans more quickly than that of the Irish, is what you are commonly told. Conversions of native Americans flying from the distractions of controversy to the repose of unity under authority there have been, but the number probably has not been large. In America, as in England, Ritualism has served Roman Catholicism as a tender. The critical question was how the religion of the Middle Ages could succeed in making itself at home under the roof of a democratic republic, the animating spirit of which was freedom, intellectual and spiritual as well as political, while the wit of its people was proverbially keen and their nationality was 578 jealous as well as strong. The Papacy may call itself universal; in reality, it is Italian. During its sojourn in the French dominions the Popes were French; otherwise they have been Italians, native or domiciled, with the single exception of the Flemish Adrian VI., thrust into the chair of St. Peter by his pupil, Charles V., and by the Italians treated with contumely as an alien intruder. The great majority of the Cardinals always has been and still is Italian. National susceptibilities, therefore, were pretty sure to be aroused. In meeting the difficulties of her new situation Rome has shown a certain measure of pliability. She has not thrust the intolerance and obscurantism of the encyclical in the face of the disciples of Jefferson. She has paid all due homage to republican institutions, alien though they are to her own spirit, as her uniform action in European politics hitherto has proved. She has made little show of relics. She has abstained from miracles. The adoration of Mary and the saints, though of course fully maintained, appears to be less prominent. Compared with the mediæval cathedral and its multiplicity of side chapels, altars, and images, the cathedral at New York strikes one as the temple of a somewhat rationalized version. Against Puritan intolerance of Popery, if any remnant of it remained, the Catholic vote has been a sufficient safeguard. To part of the American people, especially to wealthy New York, the purple of the cardinalate and the pomp of Catholic worship have of late been by no means uncongenial. Yet between the spirit of American nationality, even in the most devout Catholic, and that of the Jesuit or the native liegeman of Rome, there cannot fail to be an opposition more or less acute, though it may be hidden as far as possible under a decent veil. This was seen in the case of Father Hecker, who had begun his career as a Socialist at Brook Farm, and, as a convert to 579 Catholicism, founded a missionary order, the keynote of which was that “man’s life in the natural and secular order of things is marching towards freedom and personal independence.” This he described as a radical change, and a radical change it undoubtedly was from the sentiments and the system of Loyola. Condemnation by Rome could not fail to follow. Education has evidently been the scene of a subterranean conflict between the Jesuit and the more liberal, or, what is much the same thing, the more American section. The American and liberal head of a college has been deposed, under decorous pretences, it is true, but still deposed. Envoys have come out from Rome to arbitrate and compose. Some of the Catholic prelates, it appears, are very willing to show their liberality by co-operating in charitable work with the clergy of Protestant churches; others decline that association. One prelate, at all events, is an active politician and a conspicuous worshipper of the flag. Others strictly confine themselves to the ecclesiastical sphere. The laity in general seem to take little account of these variations, regarding them rather as personal peculiarities than as divisions of the Church. In the American or any other branch of the Roman Catholic Church freedom of inquiry and advance in thought are of course impossible. Nothing is possible but immobility, or reaction such as that of the Syllabus. Dr. Brownson, like Hecker, a convert, showed after his conversion something of the spirit of free inquiry belonging to his former state, though rather in the line of philosophy than in that of theology, properly speaking. But if he ever departed from orthodoxy he returned to it and made a perfectly edifying end.

In our survey of the religious world we are apt to leave out of sight a fourth part or more of Christendom. When the Anglican Bishops some years ago were challenged to say whether they were or were not in communion with the Eastern Church, that is with the Church of Russia, their answer 580 was in effect that the Eastern Church was so remote that they could not tell. The Russian Church has been and is, in truth, remote from the life, the progress, the thought, and the controversies of the other members of Christendom. It has passed through no crisis, undergone no change analogous either to the Reformation or to the Roman Catholic reaction. Such conflicts or controversies as it has had have been

ceremonial, not doctrinal or spiritual. Its great reformer, if he can be so called, Nicon, was a thorough-going ceremonialist and initiated no doctrinal innovation. The movement of its non-conformists, the Starovers, is not a counterpart of that of Protestant non-conformists, but a ritualistic reaction. It differs theologically from the Roman Catholic and the Anglican churches on the article in the Creed respecting the procession of the Holy Ghost. But its more practical grounds of difference probably are its abhorrence of images and of instrumental music and its practice of baptism by immersion. It is more sacramental than the Roman Catholic Church, administering the Eucharist as well as baptism to infants. While it abhors images, it adores pictures, provided they are archaic and not works of art, having an instinctive perception of the tendency of art to open the door for humanity. But it is less sacerdotal, compulsory marriage of the clergy, instead of celibacy, being its rule. Monastic it is, but its monachism is of the Eastern and eremitic type, not like the active monachism of the Franciscan, the Dominican, or the Jesuit. The Russian Church is intensely national, a character stamped upon it by the long struggle for independence against the Mohammedan Tartars. The head of the nation is the head of the Church. The Czar is Pope, as the Emperor practically was of that Byzantine Church of which the 581
Russian Church is the daughter. He presides over the ecclesiastical councils. The abolition of the Patriarchate removed the last rival of his power. Peter the Great, when asked to restore the office, exclaimed, “I am your Patriarch,” flung down his hunting knife on the table, and said, “There is your Patriarch.”

Attempts have been made both by Gallicans and Anglicans to negotiate a union with the Eastern Church as a counterpoise to the Papacy. But they have been baffled by the intense nationality and antiquated ritualism rather than by the difference about an article in the Athanasian Creed. The upshot has been the intellectual immobility of the Russian Church, whose compartment in the theological history of the last century is a blank.

Such is the position in which at the close of the last century Christendom seems to have stood. Outside the pale of reason—of reason; we do not say of truth—were the Roman Catholic and Eastern Churches; the Roman Catholic Church resting on tradition, sacerdotal authority, and belief in present miracles; the Eastern Church supported by tradition, sacerdotal authority, nationality, and the power of the Czar. Scepticism had not eaten into a Church, preserved, like that of Russia, by its isolation and intellectual torpor; though some wild sects had been generated, and Nihilism, threatening with destruction the Church as well as the state, had appeared on the scene. Into the Roman Catholic Church scepticism had eaten deeply, and had detached from her, or was rapidly detaching, the intellect of educated nations, while she seemed resolutely to bid defiance to reason by her Syllabus, her declaration of Papal infallibility, her proclamation of the Immaculate Conception of Mary. Outside the pale of traditional authority and amenable to reason stood the Protestant Churches, urgently pressed by a question as to the sufficiency of the evidences of supernatural Christianity, above all, of its vital and 582
fundamental doctrines: the Fall of Man, the Incarnation, and the Resurrection. The Anglican Church, a fabric of policy compounded of Catholicism without a Pope and Biblical Protestantism, was in the throes of a struggle between those two elements, largely antiquarian and of little importance compared with the vital question as to the evidences of revelation and the divinity of Christ.

In the Protestant churches generally æstheticism had prevailed. Even the most austere of them had introduced Church art, flowers, and tasteful music; a tendency which, with the increased craving for rhetorical novelty in the pulpit, seemed to show that the simple Word of God and the glad tidings of salvation were losing their power and that human attractions were needed to bring congregations together.

The last proposal had been that dogma, including the belief in the divinity of Christ, having become untenable should be abandoned, and that there should be formed a Christian Church with a ritual and sacraments, but without the Christian creed, though still looking up to Christ as its founder and teacher; an organization which, having no definite object and being held together only by individual fancy, would not be likely to last long.

The task now imposed on the liegemen of reason seems to be that of reviewing reverently, but freely and impartially, the evidences both of supernatural Christianity and of theism, frankly rejecting what is untenable, and if possible laying new and sounder foundations in its place. To estimate the gravity of the crisis we have only to consider to how great an extent our civilization has hitherto rested on religion. It may be found that after all our being is an insoluble mystery. If it is, we can only acquiesce and make the best of our present habitation; but who can say what the advance of 583 knowledge may bring forth? Effort seems to be the law of our nature, and if continued it may lead to heights beyond our present ken. In any event, unless our inmost nature lies to us, to cling to the untenable is worse than useless; there can be no salvation for us but in truth.

Goldwin Smith.

THE END

Transcriber's Notes

Punctuation and spelling were made consistent when a predominant preference was found in this book; otherwise they were not changed.

Simple typographical errors were corrected; occasional unbalanced quotation marks retained.

Ambiguous hyphens at the ends of lines were retained; occurrences of inconsistent hyphenation have not been changed.

Redundant chapter titles have been removed.

Text sometimes expresses fractions with a dash instead of a slash. That notation has been retained here.

The name "Van 't Hoff" always was misprinted as "Van't Hoff" in the original book. That misprint has been retained here.

Page 46: The original book used "Zu" as the symbol for zinc.

Page 122: "entirely changed by" was printed as "charged"; changed here.

Page 139: "barometric" was printed as "barometic"; changed here.