ADDRESS

BY

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Gentlemen of the British Association,

We are here met, in this our 28th annual assembly, having accepted, for the present year, the invitation of the flourishing town and firm seat of British manufacturing energy, Leeds, to continue the aim of the Association, which is the promotion of Science, or the Knowledge of the Laws of Nature; whereby we acquire a dominion over Nature, and are able so to apply her powers as to advance the well-being of society and exalt the condition of mankind. It is no light matter, therefore, the work that we are here assembled to do.

God has given to man a capacity to discover and comprehend the laws by which His universe is governed; and man is impelled by a healthy and natural impulse to exercise the faculties by which that knowledge can be acquired. Agreeably with the relations which have been instituted between our finite faculties and the phenomena that affect them, we thus arrive at demonstrations and convictions which are the most certain that our present state of being can have or act upon.

Nor let any one, against whose prepossessions a scientific truth may jar, confound such demonstrations with the speculative philosophies condemned by the Apostle; or ascribe to arrogant intellect soaring to regions of forbidden mysteries the acquisition of such truths as have been or may be established by patient and inductive research. For the most part, the discoverer has been so placed by circumstances, rather than by predetermined selection, as to have his work of investigation allotted to him as his daily duty; in the fulfilment of which he is brought face to face with phenomena into which he must inquire, and the result of that inquiry he must faithfully impart. The course of natural as of moral truth is progressive: but it has pleased the Author of all truth to vary the fashion of the imparting of such parcels thereof as He has allotted from time to time, for the behoof and guidance of mankind.

Those who are privileged with the faculties of discovery are, therefore, to be regarded as preordained instruments in making known the power of God, without a knowledge of which, as well as of Scripture, we are told that we shall err.

Great and marvellous have been the manifestations of this power imparted to us of late times, not only in respect of the shape, motions, and solar relations of the earth, but also of its age and inhabitants.

In regard to the period during which the globe allotted to man has revolved in its orbit, present evidence strains the mind to grasp such sum of past time with an effort like that by which it tries to realize the space dividing that orbit from the fixed stars and remoter nebulæ. Yet, during all those æras that have passed since the Cambrian rocks were deposited which bear the impressed record of Creative power, as it was then manifested, we know, through the interpreters of these 'writings on stone,' that the earth was vivified by the sun's light and heat, was fertilized by refreshing showers, and washed by tidal waves.

No stagnation has been permitted to air or ocean. The vast body of waters not only moved, as a whole, in orderly oscillations, regulated, as now, by sun and moon; but were rippled and agitated by winds and storms. The atmosphere was healthily influenced by its horizontal currents; and by ever-varying clouds and vapours, rising, condensing, dissolving, and falling in endless vertical circulation. With these conditions of life, we know that life itself has been enjoyed throughout the same countless thousands of years; and that with life, from the beginning, there has been death.

The earliest testimony of the living thing, whether shell, crust, or coral in the oldest fossiliferous rock, is at the same time proof that it died.

At no period has the gift of life been monopolized by a few contemporary individuals through a stagnant sameness of untold time; but it has been handed over from generation to generation, and successively enjoyed by the myriads that constitute the species. And, herein, we discern the greater beneficence and wisdom; that, through death, whether sudden or preceded by a brief decay, the individual enjoys the varying phases of life,—healthy assimilative growth, active youth, and vigorous maturity, with the procreative faculties and instincts to boot. And as life rises in the scale, even to the present highest form, foreknowing of his end, death is still the condition on which are enjoyed man's purest pleasures,—the reverential love of parents—the holy affections of wedlock—the fond yearning towards offspring.

It has further been given us to know, that not only the individual but the species perishes; that as death is balanced by generation, so extinction has been concomitant with creative power, which has continued to provide a succession of species; and furthermore, that, as regards the varying forms of life which this planet has witnessed, there has been "an advance and progress in the main."

Geology demonstrates that the Creative force has not deserted this earth during any of her epochs of time; and that in respect to no one class of animals has the manifestation of that force been limited to one epoch. Not a species of fish that now lives, but has come into being during a comparatively recent period: the existing species were preceded by other species, and these again by others still more different from the present. No existing genus of fishes can be traced back beyond a moiety of known creative time. Two entire orders have come into being, and have almost superseded two other orders since the newest of the secondary formations of the earth's crust.

The axiom of the continuous operation of Creative power, or of the ordained becoming of living things, is here illustrated by the class of fishes, because that class is exempt from the application of some exterminating causes affecting terrestrial and air-breathing animals.

But the creation of every class of such animals, whether Reptiles, Birds, or Beasts, has been successive and continuous, from the earliest times at which we have evidence of their existence. The reptiles of the coal measures, the great birds that impressed the Connecticut sandstones, and the marsupial mammals of the Stonesfield and Purbeck Oolites, came into being long before the Cycloid fishes were created and anterior to the apparition of any known existing species of aquatic animal. Species after species of land animals, order after order of air-breathing reptiles, have succeeded each other; creation ever compensating for extinction. The successive passing away of air-breathing species may have been as little due to exceptional violence, and as much to natural law, as in the case of marine plants and animals. It is true, indeed, that every part of the earth's surface has been submerged; but successively, and for long periods. Of the present dry land different natural continents have different faunæ and floræ; and the fossil remains of the plants and animals of these continents respectively show that they possessed the same peculiar characters, or characteristic *facies*, during periods extending far beyond the utmost limits of human history.

Such, gentlemen, is a brief summary of facts most nearly interesting us, which have been demonstratively made known respecting our earth and its inhabitants. And when we reflect at how late and in how brief a period of historical time the acquisition of such knowledge has been permitted, we must feel that, vast as it seems, it may be but a very small part of the patrimony of truth destined for the possession of future generations.

The certain knowledge of the very shape of the earth dates not so far back by some centuries as that epoch marked by the revelation, amongst other divine truths, of the responsibility of man for the use of the talent entrusted to him; and we may well believe that it has been mainly under the sense of this responsibility that men have submitted themselves to that patient endurance of the labour of investigation, experiment, comparison, invention, and the pondering on results, often to the utmost reach of mental tension, by which the present knowledge of the Divine power has been acquired.

In reviewing the nature and results of our proceedings during the last twenty-seven years, and the aims and objects of our Association, it seems as if we are realizing the grand Philosophical Dream or Prefigurative Vision of Francis Bacon, which he has recounted in his 'New Atlantis.'

In this noble Parable the Father of Modern Science imagines an Institution which he calls "Solomon's House," and informs us, by the mouth of one of its members, that "the end of its Foundation is the Knowledge of Causes and Secret Motions of Things; and the enlarging of the bounds of Human Empire to the effecting of all things possible."

Amongst the means and instruments to this great end, Bacon imagines laboratories situated at the greatest attainable distances, vertically, in regard to the atmosphere;—some sunk 600 fathoms deeper than the deepest natural cave; others placed on towers set upon high mountains, "so that the vantage of the hill with the tower is in the highest of them three miles at least." In the depths he conceives might be carried on the producing of new artificial metals* by compositions and materials left at work for many years, in imitation of natural mines; also observations on the formation of figured fossils; and he speculates upon the influence of these cold depths in the curing of certain diseases and the prolonging of human life, as it seems by a superinduced torpidity. In the higher regions of the air are to be carried on observations of the heavens, and of divers meteors—wind, rain, hail, and falling stars.

"We have also," he writes, "spacious houses where we imitate and demonstrate meteors, as thunders, lightnings, snow, hail, and rain. We have, also, instruments which generate heat only by motion."

Next come arrangements for the appliance of water-power and of winds to set a-going divers motions:—"engine-houses, where are prepared engines and instruments for all sorts of motions, some swifter than any known to the rest of the world, and other various motions for equality, fineness and subtilty:—a mathematical house, where are represented all instruments, as well of geometry as astromomy, exquisitely made. We have also sound-houses, where we practise and demonstrate all sounds and their generation, as by divers instruments of music; and those that imitate all articulate sounds and letters, and the voices and notes of beasts and birds. We have also the means to convey sounds in trenches and pipes in strange lines and distances." Then come the perspective-houses, "where we make demonstrations of all light and radiations and of all colours; and out of things uncoloured and transparent we can represent unto you several colours, both as rainbows and as single. We make artificial rainbows, halos and circles about light, and represent all manner of reflexions, refractions, and multiplication of visual beams of objects. These multiplications of light we carry to great distances, and make so sharp as to discern small points and lines. We procure means of seeing objects afar off, as in the heaven and remote places, representing things afar off as near. We

* Davy, Herschel, Aluminium.

have also glasses and means to see minute bodies perfectly and distinctly, as the shapes and colours of small flies and worms, which cannot otherwise be seen;" also "observations on blood and sap not otherwise to be seen."

In regard to natural history, Bacon imagines huge Aquaria, of both salt and fresh water, for the use and observation and generation of fish and fowl, "where we make trials upon fishes. We have also parks and enclosures of all sorts of beasts and birds, which we use not only for view and rareness, but likewise for dissections and trials; that thereby we may take light what may be wrought upon the body of man.

"We have also large and various orchards and gardens, wherein we do not so much respect beauty as variety of ground and soil: in these are practised all conclusions of grafting and inoculating; and we make, by art, trees and flowers to come up earlier or later than their seasons; we also make them by art much greater than their nature, and their fruit greater and sweeter, and of different taste, smell, and colour."

Lastly, as one important means of effecting the great aims of the "six days-college," certain of its members were deputed, as "merchants of light," to make "circuits or visits of divers principal cities of the kingdom."

This latter feature of the Baconian organisation is the chief characteristic of the "British Association;" but we have striven to carry out other aims of the 'New Atlantis,' such as the systematic summaries of the results of different branches of science, of which our published volumes of 'Reports' are evidence; and we have likewise realized, in some measure, the idea of the 'Mathematical House' in our establishment at Kew.

The national and private Observatories, the Royal and other Scientific Societies, the British Museum, the Zoological, Botanical, and Horticultural Gardens combine in our day to realize that which Bacon foresaw in distant perspective. Great beyond all anticipation have been the results of this organisation, and of the application of the inductive methods of interrogating Nature.

The universal law of gravitation, the circulation of the blood, the analogous course of the magnetic influence, which may be said to vivify the earth, permitting no atom of its most solid constituents to stagnate in total rest; the development and progress of Chemistry, Geology, Palæontology; the inventions and practical applications of gas, the steam-engine, photography, telegraphy:—such, in the few centuries since Bacon wrote, have been the rewards of the faithful followers of his rules of research.

We can hardly appreciate the swift of progress of human knowledge unless we go back, for an instant, to the period whice I have chosen as the starting-point in this survey.

Bacon's treatment of the Copernican theory shows the importance of pure observation in the establishment of natural truth, and places in a strong light the incompetency of the highest intellectual power, of itself, to reason up to truth, even when it is so plain as it now appears to us in reference to the true nature of the apparent movements of the sun in respect to the earth.

The well-known passages from the 'Thema Cœli,' and the essay 'On the

Cause of the Tides,' together with the fling "at those few carmen which drive the earth about*," are strongly indicative of the state of Bacon's mind —the philosophical mind of his time—on the great question then agitating it, as to the movements of the heavenly bodies.

A mass of observations of their apparent movements had been accumulating from the periods of Hipparchus and Ptolemy to that of Copernicus. The nature and cause of those observed movements had to be explained. The Alexandrian astronomer had given an explanation in harmony with the apparent motions. Copernicus suggested another, contradictory of the apparent motions, but more in harmony, through certain reasons assigned, with what he believed to be their real nature.

These reasons wanted proofs from observation; but the proofs afterwards came, and were the fruit of the more commonly possessed inventive faculty rather than of the rarer power of abstract thought. Great, truly, is the gift to mankind when the two faculties coexist in a commanding intellect!

Galileo invented a perspective glass by which he discovered the four small bodies which revolve about Jupiter in different periods of time. The analogy which this visible system of Jupiter bore to the solar system, as conceived by Copernicus, gave what Herschel calls the "holding turn" to the opinions of mankind respecting the heliocentric system. Galileo's next discovery more decidedly confirmed the truth of that system. He observed that Venus in the course of her revolution assumed the same succession of phases which our moon exhibits in her monthly circuit. The opponents of Copernicus had objected that Venus did not appear four times as large as she should do when, according to his system, she is four times as near us; but Galileo furnished the true reason: the dark side of Venus is toward the earth when she is nearest it. But with all this, Bacon's acceptance of the Copernican system never went further than as respected the movements of Venus and Mercury about the Sun.

My motive in here referring to such trite facts in the History of Astronomy is to impress upon all who sympathize with scientific progress, or merely wish us 'good speed,' the importance of direct observation of Nature. The two results of Galileo's direction of his telescope to heavenly bodies were of more value than the subtlest of the objections of Bacon or of the excuses of Bruno.

In 1631 Kepler witnessed the transit of Mercury across the sun's disk: in 1639 Horrox saw the like transit of Venus: and these observations were of a higher kind than Galileo's. His might be called a chance trial of the phenomena of the skies; the English astronomer planted his telescope at the very hour, when, according to the Copernican hypothesis, he had calculated that Venus in her orbit would pass between the sun and the earth. Kepler's observation of the elliptical form of the orbit of Mars definitely cast out the eccentrics and epicycles of Ptolemy, and made the Copernican explanation easier than it had seemed to Copernicus himself.

* Discourse 'In Praise of Knowledge.'

The motions of the heavenly bodies being thus determined, there remained their cause, or their laws. Kepler's successive approximations to an accurate determination of the orbits of the planets, and to the ratios of their mean distances from the sun to the times of their revolutions, which mathematicians now express by saying that "the squares of the periodic times are in the same proportion as the cubes of the distance," became an important prelude to Newton's discovery of the law of the sun's attractive force.

Without stopping to trace the concurrent progress of the science of motion, of which the true foundations were laid, in Bacon's time, by Galileo, it will serve here to state that the foundations were laid and the materials gathered for the establishment, by a master-mind, supreme in vigour of thought and mathematical resource, of the grandest generalization ever promulgated by science—that of the universal gravitation of matter according to the law of the inverse square of the distance.

The same century in which the 'Thema Cœli' of Lord Verulam and the 'Nuncius Sidereus' of Galileo saw the light, was glorified by the publication of the 'Philosophiæ Naturalis Principia Mathematica' of Newton.

Has time, it may be asked, in any way affected the great result of that masterpiece of human intellect? There are signs that even Newton's axiom, or the terms in which it was enunciated, may not be exempt from the restless law of progress.

The mode of expressing the law of gravitation as being "in the inverse proportion of the square of the distances," involves the idea that the force emanating from or exercised by the sun must become more feeble in proportion to the increased spherical surface over which it is diffused. So, indeed, it was expressly understood by Halley.

The ablest historian of Natural Science has remarked that "future discoveries may make gravitation a case of some wider law, and may disclose something of the mode in which it operates*." The difficulty, indeed, of conceiving a force acting through nothing from body to body has of late made itself felt; and more especially since Meyer of Heilbron first clearly expressed the principle of the 'conservation of force.' Newton, though apprehending the necessity of a medium by which the force of gravitation should be conveyed from one body to another†, yet appears not to have possessed such an idea of the indestructibility of force as that which, now possessed by minds of the highest order, seems to some of them to be incompatible with the terms in which Newton enunciated his great law; viz. of matter attracting matter with a force which varies inversely as the square of the distance.

Faraday has offered the following comment on this received expression of the idea of gravity:—"Assume two particles of matter, A and B, in free space, and a force in each or in both by which they gravitate

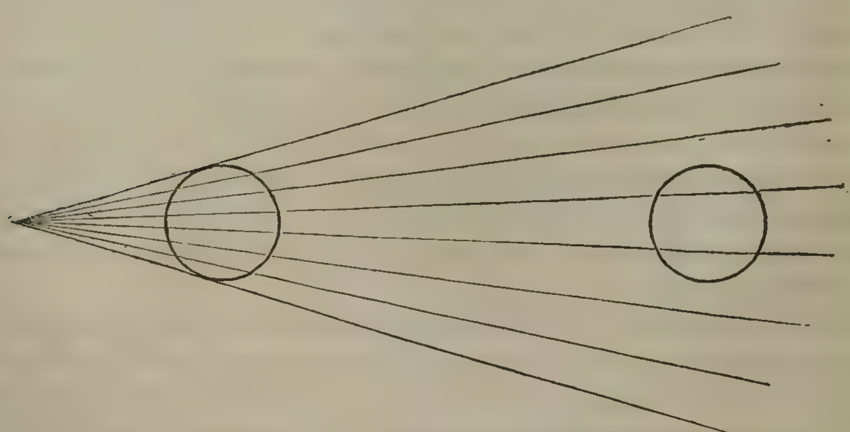
* Whewell, History of the Inductive Sciences.

† See Newton's Third Letter to Bentley.

towards each other, the force being unalterable for an unchanging distance, but varying inversely as the square of the distance, when the latter varies. Then, at the distance of 10 the force may be estimated as 1; whilst at the distance of 1, *i. e.* one-tenth of the former, the force will be 100: and if we suppose an elastic spring to be introduced between the two as a measure of the attractive force, the power compressing it will be a hundred times as much in the latter case as in the former. But from whence can this enormous increase of the power come? If we say that it is the character of this force, and content ourselves with that as a sufficient answer, then, it appears to me, we admit a *creation* of power, and that to an enormous amount; yet by a change of condition, so small and simple as to fail in leading the least-instructed mind to think that it can be a sufficient cause, we should admit a result which would equal the highest act our minds can appreciate of the working of infinite power upon matter; we should let loose the highest law in physical science which our faculties permit us to perceive, namely, the *conservation of force.* Suppose the two particles A and B removed back to the greater distance of 10, then the force of attraction would be only a hundredth part of that they previously possessed; this, according to the statement that the force varies inversely as the square of the distance, would double the strangeness of the above results; it would be an *annihilation* of force: an effect equal in its affinity and its consequences with *creation*, and only within the power of Him who has created."

If we suppose the different modes of force, which we call 'light,' 'heat,' 'gravity,' to act in all directions, as emanations from a centre, with a force which is the same in every part of the line, throughout space, the law of the 'inverse squares' would be a necessary consequence of the fact that, at double the distance, only one-fourth the number of such 'lines of force' would impinge or act upon the 'illuminated,' 'heated' or 'attracted' body *.

This may be understood by the subjoined diagram:—



* Westminster Review, No. XXVII.

So much in illustration of the present phase of scientific thought in reference to the Newtonian axiom.

The progress of knowledge of the form of all-pervading force, which we call, from its most notable effect on one of the senses, 'light,' has not been less remarkable than that of gravitation.

Galileo's discovery of Jupiter's satellites supplied Römer with the phenomena whence he was able to measure, in 1676, the velocity of light. Descartes, in his theory of the Rainbow, referred the different colours to the different amount of refraction, and made a near approximation to Newton's capital discovery of the different colours entering into the composition of the luminous ray, and of their different refrangibility. Hook and Huyghens, about the same period had entered upon explanations of the phenomena of light conceived as due to the undulations of an ether, propagated from the luminous point spherically, like those of sound. Newton, whilst admitting that such undulations or vibrations of an ether would explain certain phenomena, adopted the hypothesis of emission as most convenient for the mathematical propositions relative to light. The discoveries of achromatism, of the laws of double refraction, of polarization circular and elliptical, and of depolarization, rapidly followed, realizing more than Bacon conceived might flow from the labours of the 'perspective house,' and, with later advances in optics, have made renowned the names of Dollond, Young, Malus, Fresnel, Arago, Biot, Brewster, Stokes, and Jamin.

Some of the natural sciences, as we now comprehend them, had not germinated in Bacon's time. Chemistry was then Alchemy: Geology and Palæontology were undreamt of: but Magnetism and Electricity had begun to be observed, and their phenomena compared and defined by a contemporary of Bacon, in a way that claims to be regarded as the first step toward a scientific knowledge of those powers. It is true that, before Gilbert*, the magnet was known to attract iron, and the great practical application of magnetized iron—the mariner's compass—had been invented, and for many years before Bacon's time had guided the barks of navigators through trackless seas.

Gilbert, to whom the name 'electricity' is due, observed that that force attracted light bodies, whereas the magnetic force attracted iron only. About a century later the phenomena of repulsion as well as of attraction of light bodies by electric substances were noticed; and Dufay, in 1733, enunciated the principle that "electric bodies attract all those that are not so, and repel them as soon as they are become electric by the vicinity of the electric body."

The conduction of electric force, and the different behaviour of bodies in contact with the electric, leading to their division, by Desaguliers, into conductors and non-conductors, next followed. The two kinds of electricity, at first by Dufay, their definer, called 'vitreous' and 'resinous,' afterwards, by

* De Magnete (1600).

Franklin, 'positive' and 'negative,' formed an important step, which led to a brilliant series of experiments and discoveries, with inventions, such as the Leyden jar, for intensifying the electric shock. But whilst the majority of the applications of these degrees of mastery over the electric force was calculated to amuse or surprise, the instantaneous transmission of electricity through an extent of 6000 feet, demonstrated by Sir W. Watson, together with Franklin's discovery of the electric state of the clouds, and of the power of drawing off such electricity by pointed bodies, was a brilliant beginning of the application of this subtle science to the discovery of the well-being and needs of mankind. Superstitious ignorance might well shrink from playing, as the American philosopher with his electric kites seemed to be doing, with lightning,—might gaze with alarm at the Russian Professor * collecting on his electrical rod the awful charge of the black thunder-cloud,—might deem the globe of fire which leapt from the rod upon the head of the experimenter and struck him dead as a judgment for tampering with a force that man's instinct, in all ages, has referred to a direct expression of the power and will of Deity. But the cultivator of God's intellectual gifts sees rather, in the application of the lightning-conductors which now guide harmless to the earth the dangerous electricity of the clouds, the predestined fruit and reward of the laborious and dauntless application of those gifts, agreeably with the rule of right reason, to the unfolding of natural phenomena.

To hide from the lightning and tremble at the thunder, as the immediate manifestation of offended Deity, is the superstition of the savage: to recognize that both phenomena are under the control of a law, and operating to beneficial ends, is the privilege of the sage. This it is which begets a true and worthy feeling of reverence for the Lawgiver.

When the knowledge of the law gives the mode of diverting from the well-manned ship and the crowded hall the destructive influence of the electric bolt, we then worthily adore the beneficence that has imparted so much of the power-interpreting talent as brings that reward for its enjoined use. The philosopher, in the course of his hazardous experimental researches, may incur a fatal result; but he becomes then, not the sacrifice for presumptuous espial into divine and forbidden mysteries, but the true 'martyr of science.' His death has contributed to save the lives of thousands of his fellow-creatures and to allay the distressing fears of millions.

Magnetism has been studied with two aims,—the one to note the numerical relations of its activity to time and space, both in respect of its direction and intensity, the other to penetrate the mystery of the nature of the magnetic force.

In reference to the first aim, my estimable predecessor adverted, last year, to the fact that it was in the Committee-rooms of the British Association that the first step was taken towards that great magnetic organization which has since borne so much fruit. Thereby it has been determined that there

* Richmann.

are periodical changes of the magnetic elements depending on the hour of the day, the season of the year, and on what seemed strange intervals of about eleven years. Also, that besides these regular changes there were others of a more abrupt and seemingly irregular character—Humboldt's 'magnetic storms'—which occur simultaneously at distant parts of the earth's surface. Major-General Sabine, than whom no individual has done more in this field of research since Halley first attempted "to explain the change in the variation of the magnetic needle," has proved that the magnetic storms observe diurnal, annual, and decennial periods. But with what phase or phenomenon of earthly or heavenly bodies, it may be asked, has the magnetic period of ten years to do? The coincidence which points to, if it does not give, the answer, is one of the most remarkable, unexpected, and encouraging to patient observers.

For thirty years a German astronomer, Schwabe, had set himself the task of daily observing and recording the appearance of the sun's disk; in which time he found that the spots passed through periodic phases of increase and decrease, the length of the period being about ten years. A comparison of the independent evidence of the astronomer and magnetic observer has shown that the decennial magnetic period coincides both in its duration and in its epochs of maximum and minimum with the same period observed in the solar spots.

A few weeks ago, during a visit of inspection to our establishment at Kew, I observed the successful operation of the photoheliographic apparatus in depicting the solar spots as they then appeared. The continued regular record of the macular state of the sun's surface, with the concurrent magnetic observations now established over many distant points of the earth's surface, will ere long establish the full significance and value of the remarkable, and, in reference to the observers, undesigned, coincidence above mentioned.

Not to trespass on your patience by tracing the progress of magnetism from Gilbert to Oersted, I cannot but advert to the time, 1807, when the latter tried to discover whether electricity in its most latent state had any effect on the magnet, and to his great result, in 1820, that the conducting-wire of a voltaic circuit acts upon a magnetic needle, so that the latter tends to place itself at right angles to the wire.

The ablest physicists in Europe, and Ampère especially, devoted themselves, immediately on the promulgation of this capital discovery, to the analysis of its conditions. Ampère, moreover, succeeded, by means of a delicate apparatus, in demonstrating that the voltaic wire was affected by the action of the earth itself as a magnet. In short, the generalization was established, that *magnetism and electricity are but different effects of one common cause.* This has proved the first step to still grander abstractions—to that which conceives the reduction of all the species of imponderable fluids of the chemistry of our student days, together with gravitation, chemicity*,

* 'Elective' or 'molecular attraction.'

and neuricity*, to interchangeable modes of action of one and the same all-pervading life-essence.

Galvani arranged the parts of a recently-mutilated frog so as to bring a nerve in contact with the external surface of a muscle, when a contraction of the muscle ensued. In this suggestive experiment the Italian philosopher, who thereby initiated the inductive inquiry into the relation of nerve force to electric force, concluded that the contraction was a necessary consequence of the passage of electricity from one surface to the other by means of the nerve. He supposed that the electricity was secreted by the brain, and transmitted by the nerves to different parts of the body, the muscles serving as reservoirs of the electricity. Volta made a further step, by showing that, under the conditions or arrangements of Galvani's experiments, the muscle would contract, whether the electric current had its origin in the animal body, or from a source external to that body. Galvani erred in too exclusive a reference of the electric force producing the contraction to the brain of the animal: Volta in excluding the origin of the electric force from the animal body altogether. The determination of 'the true' and 'the constant' in these recondite phænomena has been mainly helped on by the persevering and ingenious experimental researches of Matteucci and Du Bois Reymond. The latter has shown that any point of the surface of a muscle is positive in relation to any point of the divided or transverse section of the same muscle; and that any point of the surface of a nerve is positive in relation to any point of the divided or transverse section of the same nerve. Mr. Baxter, in still more recent researches, has deduced important conclusions on the origin of the muscular and nerve currents, as being due to the polarized condition of the nerve or muscular fibre, and the relation of that condition to changes which occur during nutrition. From the present state of neuro-electricity it may be concluded that nerve force is not identical with electric force, but that it may be another mode of motion of the same common force: it is certainly a polar force, and perhaps the highest form of polar force:—

> "A motion which may change, but cannot die;
> An image of some bright eternity."

The present tendency of the higher generalizations of chemistry seems to be toward a reduction of the number of those bodies which are called 'elementary;' it begins to be suspected that certain groups of so-called chemical elements are but modified forms of one another.

An important step in the elimination of the chlorine and bromine group from the category of simple bodies or elements has very recently been made by Prof. Schönbein. He, at least, adduces strong reasons, from analogy, for regarding those substances as 'oxy-compounds,' or what the Professor terms 'Ozonides;' chlorine being, according to this view, the peroxide of murium$=MuO+\Theta$. The researches on which this conclusion is founded have recalled to my mind the cautious terms in which my venerable Teacher

* Force ascribed to a nervous fluid.

of Chemistry, Hope, always introduced Davy's then new hypothesis; and I now better appreciate the celebrated Edinburgh Professor's disinclination to abandon the old doctrine of the compound nature of chlorine, &c.

Organic chemistry becomes simplified as it expands; and its growth has, of late, proceeded, through the labours of Hoffmann, Berthelot, and others, with unexampled rapidity. The results of the recent experiments of M. Berthelot have more especially tended to reduce the various and numerous ternary oxygenated organic substances into a small number of fundamental groups. The important power of synthesis has grown with this growth. Since Wöhler, in 1828, succeeded in artificially producing 'urea,' Kolbe has similarly, by the combinations of inorganic elements, produced acetic acid and the new organic radical 'methyl.' Berthelot has formed glycerine, the basis of animal and vegatable oils and fats, and has also formed grape-sugar. It is true, that in the latter synthesis the contact of putrefying animal matter is requisite; although such matter contributes none of its constituents to the new compound, nor undergoes any appreciable change in the process. Berthelot has very recently shown that cholesterine is a true alcohol, analogous to éthal; and that, treated by acids, it is transformed into corresponding ethers, similar to other éthilic ethers.

A substance resembling camphor has been this year made by the action of acids, *e.g.*, the chorhydric, upon essential oil of turpentine. By treating this substance with strong alkali it is changed into a liquid carburet of hydrogen; but, if feeble alkalis are employed or slightly alkaline salts, a solid carburet is obtained identical with camphor. By oxidizing the artificial camphor, ordinary camphor is obtained; by adding hydrgoen to such ordinary camphor, the camphor of Borneo is obtained. M. Berthelot has thus realized the synthetic preparation of camphors.

An important series of alcohols and their derivatives, from amylic alcohol downwards; as extensive a series of ethers, including those which give their peculiar flavour to our choicest fruits; the formic, butyric, succinic, lactic, and other acids, together with other important organic bodies, are now capable of artificial formation from their elements, and the old barrier dividing organic from inorganic bodies is broken down. To the power which mankind may ultimately exercise through the light of synthesis, who may presume to set limits! Already natural processes can be more economically replaced by artificial ones in the formation of a few organic compounds, the 'valerianic acid,' for example. It is impossible to foresee the extent to which Chemistry may not ultimately, in the production of things needful, supersede the present vital agencies of nature "by laying under contribution the accumulated forces of past ages, which would thus enable us to obtain in a small manufactory, and in a few days, effects which can be realized from present natural agencies, only when they are exerted upon vast areas of land, and through considerable periods of time*."

* Frankland, Lecture, Royal Institution, May 28, 1858.

Since Nièpce, Herschel, Fox Talbot, and Daguerre laid the foundations of Photography, year by year some improvement is made, some advance achieved, in this most subtle application and combination of discoveries in Photicity, Electricity, Chemistry, and Magnetism.

Last year M. Poiteven's production of plates in relief, for the purpose of engraving by the action of light alone, was cited as the latest marvel of photography. This year has witnessed photographic printing in carbon. M. Pretschi's method is as follows :—

" A photograph or engraving is placed on the prepared plate, and a negative taken in sun-light. The glass is then placed in water with a little alcohol, and the darkened parts are rendered soluble, while the other parts are insoluble, so that in a few minutes we have a picture represented not only by light and shadow, but by the unequal thickness of the gelatine on the glass. When the plate is dry, soft gutta-percha is pressed upon the picture till it hardens. The gutta-percha has consequently an image the reverse of the first. After rubbing it over with bronze powder or black-lead, it is placed in a solution of sulphate of copper, and an electrotype plate taken from it, in the usual way, with a voltaic battery. From this plate others can be readily taken, and, as in ordinary copperplate printing, thousands of copies can be thrown off. 'By this process,' says Mr. Hunt, 'pictures, in which the most delicate details are very faithfully preserved, and the nice gradations in light and shadow maintained in all their beauty, are now printed from the electrotype plate, obtained from the photograph. The process of photo-galvanography is evidently destined to take a very high position as a means of preserving the beauties of nature and art.' "

M. Nièpce de St. Victor has succeeded in reproducing the colour of the original on metallic plates; though he cannot fix it. Unfortunately these lovely 'heliochromes' vanish like the breath from the mirror.

M. Delarue has obtained photographs of the moon in which the details of its illuminated surface are well defined—the cone in 'Tycho,' the double cone in 'Copernicus,' and even the ridge of 'Aristarchus.' A photograph of the planet Jupiter has been obtained in which the belts are very well marked and the satellites distinct.

The portrait of a 13-inch shell has been secured while in full flight, a few feet after it left the mortar; and, in effecting this, Mr. Scaife has obtained a representation of phenomena in the development of the smoke too transitory for the eye to ascertain when they occur. The photographic eye is, in fact, more sensitive than the living one: it can receive and register impressions too fine for human vision, until made visible by increased light and developing agents. Hence, photography may superadd a new defining function to the highest attainable telescopic power.

Photography is now a constant and indispensable servant in certain important meteorological records. Applied periodically to living plants, photography supplies the botanist with the easiest and best data for judging of their rate of growth. It gives to the zoologist accurate representations of the most complex of his subjects, and of their organization, even to microscopic details.

The engineer at home can ascertain by photographs transmitted by successive mails the weekly progress, brick by brick, board by board, nail by nail, of the most complex works on the Indian or other remote rail-roads. The physician can register every physiognomic phase accompanying the access, height, decrease, and passing away of mental disease.

The humblest emigrant may carry with him miniatures, such as Dow could not have equalled in the perfection of their finish, of scenes and persons which will recall and revive the dearest affections of the home he has left.

In its lowest application photography becomes an instrument of the criminal police.

The first practical application of the electro-magnetic discovery was, as it should be, to the direct service of the philosophic inquirer: it was such an application of a delicate compass-needle as would show, by its deflection, the strength of the voltaic current. The possession of Schweigger's 'galvanometer' enabled the philosopher henceforth to detect and measure the minutest electro-dynamic actions. It led to the discovery by Seebeck of the conversion of heat into that kind of action; in short, of thermo-electricity.

On Faraday's demonstration—the converse of Oersted's—that magnetism could produce electricity, and on the brilliant series of discoveries of that most exemplary investigator of natural laws, I need not dwell, in the presence of so many who are better qualified than myself to comprehend and illustrate them.

Remote as such profound conceptions and subtle trains of thought seem to be from the needs of every-day life, the most astounding of the practical augmentations of man's power has sprung out of them. Nothing might seem less promising of profit than Oersted's painfully-pursued experiments, with his little magnets, voltaic pile, and bits of copper-wire. Yet out of these has come the electric telegraph! Oersted himself saw such an application of his convertibility of electricity into magnetism; and Schilling successfully applied the principle to the instantaneous communication of signs through distances of a few miles. The unrivalled resources of Wheatstone's inventive genius have made it practicable for all distances, as we have lately seen in the submergence and working of the electro-magnetic cord connecting the Old with the New World.

Whoever has been engaged in the delicate physical and chemical experiments required in the present state of natural philosophy, will know how small is the expectation of success on the first trial of a new experiment in the laboratory. Only the experienced manipulator realizes how hard it is to foresee every condition requisite for success: but it is he who bears the bravest heart under failures, well assured that through them are acquired the conditions of success, and that every cause of failure, well ascertained, is an encouragement to the repetition of the trial. Every practical physicist, therefore, was prepared to expect a certain number of instructive failures in the attempt to carry out the grandest philosophical experiment on record—the most stupendous which mortal mind ever ventured to propose to itself. Our surprise is, that the failures were so few,—the success so speedy. But the persevering and determined men who achieved this success, temporary as it has been, were animated by the spirit in which Lord Bacon tells us experimental philosophy should be entered upon:—"For there is no comparison," he writes, "between that which we may lose by not trying and by not succeeding; since by not trying we throw away the chance of an immense good, by not succeeding we only incur the loss of a little human labour."

On the 6th of August, 1858, the laying down of upwards of 2000 nautical miles of the telegraphic cord, connecting Newfoundland and Ireland, was successfully completed; and shortly after, a message of thirty-one words was transmitted in thirty-five minutes along the sinuosities of the submerged hills and valleys forming the bed of the great Atlantic. This first message ended by expressing—"GLORY TO GOD IN THE HIGHEST: ON EARTH PEACE, GOODWILL TOWARDS MEN." Never since the foundations of the world were laid could it be more truly said, "The depths of the sea praise Him!"

More remains to be done before the far-stretching, thought-bearing engine can be got into full working order; but the capital fact, viz., the practicability of bringing America into electrical communication with Europe has been demonstrated; consequently a like power of instantaneous interchange of thought between the civilized inhabitants of every part of the globe becomes only a question of time. The powers and benefits thence to ensue for the human race can be but dimly and inadequately foreseen. Some results stand out more prominently than others.

The investigator of natural laws manifests his success by the degree in which he elicits and substitutes latent natural force for manual labour in effecting his purpose. Sennacherib, as we see on the slabs from Nineveh, added the lever to traction in the transport of the colossal symbolic statues of his majesty; but the power by which he worked both mechanical adjustments was slaves stimulated by the stick. Hundreds of human beings were sacrificed in the operation. WATT achieved an equal effect by the scientific eduction and direction of the latent force contained in a few pounds of coal.

If this test be applied to the present state of the science of governing peoples, it would seem to show but little progress therein. The conscription committee of France for 1858 proposed a levy of 100,000 men, because less would not suffice to keep up the requisite army of 500,000 men; Europe being at peace. Even the United States of America have progressively increased their standing army to a present total of 17,000 men.

The probability of a further augmentation of the military force of the Federal Government, in reference to a possible rupture with the Mother-country, must be greatly diminished by an ocean telegraph. And we may confidently hope that this and other applications of pure science will tend to abolish wars over the whole earth; so that men may come to look back upon the trial of battle between misunderstanding nations, as a sign of a past state of comparative barbarism; just as we look back from our present phase of civilization in England upon the old border-warfare.

Bacon, commenting on the History of the Works of Nature, as it presented itself to him, describes it as a chaos "of fables, antiquities, quotations, frivolous disputes, philology, ornaments, and table-talk." Since his day the chief steps, by which Natural History has advanced to the dignity of a science, are associated with the names of Ray, Linnæus, Jussieu, Buffon, and Cuvier.

By the two former the phenomena were digested and classified, according to artificial but conveniently applicable methods; of necessity the precursors of systems more expressive of the natural affinities of plants and animals.

To perfect the natural system of plants has been the great aim of botanists since Jussieu. To obtain the same true insight into the relations of animals has stimulated the labours of zoologists since the writings of Cuvier. To that great man appertains the merit of having systematically pursued and applied anatomical researches to the discovery of the true system of distribution of the animal kingdom: nor, until the Cuvierian amount of zootomical science had been gained, could the value and importance of Aristotle's 'History of Animals' be appreciated. The Greek philosopher, in this department of science, had advanced far beyond his systematic depreciator, Bacon, who could not, in fact, in the then state of natural knowledge, comprehend his discoveries. Such was the low state of Zoology in the interval between Aristotle and Cuvier, that there is no similar instance, in the history of science, of the well-lit torch gradually growing dimmer and smouldering through so many generations and centuries before it was again fanned into brightness, and a clear view regained, both of the extent of ancient discovery, and of the true course to be pursued by modern research.

Rapid and right has been the progress of Zoology since that resumption.

Not only has the structure of the animal been investigated, even to the minute characteristics of each tissue, but the mode of formation of such constituents of organs, and of the organs themselves, has been pursued from the germ, bud, or egg, onward to the maturity and decay of the individual.

To the observation of outward characters is now added that of inward organization and developmental change, and Zootomy, Histology, and Embryology combine their results in forming an adequate and lasting basis for the higher axioms and generalizations of Zoology properly so called.

Three principles, of the common ground of which we may ultimately obtain a clearer insight, are now recognized to have governed the construction of animals:—unity of plan, vegetative repetition, and fitness for purpose. The last, alone, has of late been questioned: but, in reference to such structures as are exemplified by the flood-gates of the heart and the lens of the eye, I find my own powers of conception and expression such as to leave me no other mode of understanding myself, or of being intelligible to others, than by using the terms 'aim,' 'end,' 'purpose,' or 'design,' in regard to the relation of the first instanced structure to the course of the blood in the circulatory system; and of the second to the convergence of light in the act of vision.

The independent series of researches by which students of the Articulate animals have seen, in the organs performing the functions of jaws and limbs of varied powers, the same or homotypal elements of a series of like segments constituting the entire body, and by which students of the Vertebrate animals have been led to the conclusion that the maxillary, mandibular, hyoid, scapular, costal and pelvic arches, and their appendages sometimes forming limbs of varied powers, are also modified elements of a series of essentially similar vertebral segments,—mutually corroborate their respective conclusions. It is not probable that a principle which is true for *Articulata* should be false for *Vertebrata*: the less probable, since the determination of homologous parts becomes the more possible and sure in the ratio of the perfection of the organization.

The last proposition may be tested by a study of any single set of organs with a view to determine their homologies.

Take, for instance, the teeth, or the organs properly so called, which are peculiar to the vertebrate animals. One cannot trace any particular tooth, as one may a bone, from Fish to Fish: they are too numerous and too uniform. In Reptiles we may point to the maxillary poison-tooth of a Rattlesnake as answering to that in a Cobra; the homological relations of the teeth being only predicable in a general way, as premaxillary, maxillary, mandibular, palatine, in the rest of that class. But when we come to the Mammalia, we find, save in a few inferior groups resembling fishes (e. g. *Cetacea*) or resembling reptiles (*Bruta*), that the teeth have such determinate characters, from relative position and development, as to enable the anatomist to trace each individual tooth from species to species, and indicate it, throughout that large proportion of the class which has been called 'diphyodont,' by a determinate name and symbol.

And here I would repeat, what I have elsewhere expressed, that each year's experience strengthens the conviction that the right and quick progress of the knowledge of animal structures, and of the axioms deducible therefrom, will be mainly influenced by the determination of homologies and by the concomitant power of condensing the propositions relating to homologized parts, by means of definite single substantive names, and their equivalent signs or symbols.

In my work on the 'Archetype of the Skeleton,' I have denoted most of the bones by numerals, which, when adopted, may take the place of names; for then all propositions respecting the centrum of the occipital vertebra might be predicated of '1' as intelligibly as of 'basioccipital.' The name appears to be now generally accepted, and why not the symbol? The symbols of the teeth are as definite as those of the bones; and, in the absence of single names, more useful, since they render unnecessary the repetition of the compound definitions; they harmonize conflicting synonyms, serve as a universal language, and express the writer's meaning in the fewest and clearest terms. The entomologist has realized the advantage of signs, such as ♂, ♀, &c. for male, female, neuter, and the like; and the time is come when the anatomist may avail himself of this powerful instrument of thought, instruction, and discovery, from which the chemist, the astronomer, and the mathematician have obtained such important results.

To William Sharp Macleay, author of the 'Horæ Entomologicæ,' belongs the merit of first clearly defining and exemplifying, in regard to the similarities observable between different animals, the distinction between those that indicate 'affinity' and those that indicate 'analogy' or representation. This distinction has been well illustrated by Vigors in the class of Birds, and has been ably discussed by Swainson in reference to other classes of animals.

'Affinity,' as first defined by Macleay in contradistinction from 'analogy,' signifies the relationship which one animal bears to another in its structure, and is the closer as the similarity of structure is greater. Swainson illustrates this idea by comparing a goatsucker with a swallow and with a bat: with the one its relation is *intimate*, with the other *remote*: the goatsucker has affinity with the swallow, analogy to the bat.

But the idea of the foregoing intimate relation of entire animals, called 'affinity,' is different from the idea of the answerable relation of parts of animals called 'homology.' Animals, however intimately 'affined,' are never the same in the sense in which homologous parts are so esteemed: they could never be called by the same name, in the way or sense in which a bone, for example, of the fore-limb, is called 'humerus' in the goatsucker, swallow, and bat.

There is, indeed, a sameness in the idea of 'analogy,' as applied by the Zoologist to animals, and by the Anatomist to their parts. The goatsucker is related by analogy to a bat, because, as Mr. Swainson remarks, "it flies at the same hour of the day, and feeds in the same manner;" and the membranous wing of the bat is analogous to the membranous parachute of the dragon, because it serves to sustain the body in the air. That is to say, 'function'—a similar relationship to a tertium quid—in the above instance air,—is the groundwork for predicating analogies in regard to parts as well as wholes; more especially when, as in the case of the wings of the dragon and bat, they are not homologous parts.

The study of homologous parts in a single system of organs—the bones—has mainly led to the recognition of the plan or archetype of the highest primary group of animals, the *Vertebrata.* The next step of importance will be to determine the homologous parts of the nervous system, of the muscular system, of the respiratory and vascular system, and of the digestive, secretory, and generative organs in the same primary group or province. I think it of more importance to settle the homologies of the parts of a group of animals constructed on the same general plan, than to speculate on such relations of parts in animals constructed on demonstratively distinct plans of organization. What has been effected and recommended, in regard to homologous parts in the *Vertebrata*, should be followed out in the *Articulata* and *Mollusca.*

In regard to the constituents of the crust or outer skeleton and its appendages in the *Articulata*, homological relations have been studied and determined to a praiseworthy extent, throughout that province.

The same study is making progress in the *Mollusca* ; but the grounds for determining special homologies are less sure in this subkingdom. The vegetative functions here predominate; and just as the organs of these functions are less satisfactory subjects of homological determination than those of the animal functions in the Vertebrate province, so the Molluscous province is a less favourable field for homological demonstrations than either the Articulate or Vertebrate provinces, in which the animal functions predominate over the vegetative.

So far as homologies can be determined, within the limits in which such determination can be most satisfactorily carried out, the foundation will be securely laid for a superstructure of higher generalizations in regard to parts homological or answerable throughout the animal kingdom generally.

The present state of homology in regard to the *Articulata* has sufficed to demonstrate that the segment of the crust is not a hollow expanded homologue of the segment of the endoskeleton of a vertebrate. There is as little homology between the parts and appendages of the segments of the Vertebrate and Articulate skeletons respectively. The parts called mandibles, maxillæ, arms, legs, wings, fins, in Insects and Crustaceans, are only 'analogous' to the parts so called in Vertebrates.

To express finitely the clear deideas now possessed of their essential distinction, will require a distinct nomenclature. The same remark is applicable to other systems of organs. The so-called 'lungs' of the spider are analogous to, not homologous with, our 'lungs:' the tracheæ of insects are not homologous with the bird's trachea and its ramifications: the gills of the lobster are not the homologous parts of the gills of fishes. No comparative anatomist now supposes that the heart of the lobster is homologous with that of a fish : or either of these organs with the heart of a snail. The name in each group is simply expressive of similarity of function, and of connexions limited by and solely related to such function, as of the heart with a vein and an artery. A most extensive field of reform is becoming open to the homologist in that which is essential to the exactitude of his science—a nomenclature equivalent to express his convictions of the different relations of similitude. Most difficult and recondite are the questions in face of which the march of homology is now irresistibly conducting the philosophic observer. Such, for instance, as the following:—Are the nervous, muscular, digestive, circulating and generative systems of organs more than functionally similar in any two primary provinces of the animal kingdom? Are the homologies of entire systems to be judged of by their functional and structural connexions, rather than by the plan and course of their formation in the embryo?

In the development of animals the vitellus is observed to have different relations to the embryo. But such difference is not always or absolutely associated with a difference of plan of structure: the Cephalopods show a higher development of the same fundamental plan of structure as that of the Gasteropods, but the vitelline phenomena of their development resemble those of *Vertebrata*, not those of *Gasteropoda*.

Even in the last-named restricted molluscous group there are striking differences in the vitelline relations of the embryo. In most the embryo early encloses the vitelline mass; in some, as in *Limax*, much later: and there is what may be termed a temporary vitelline sac.

The yolk undergoes a complete segmentation in placental Mammals, the embryo of which is formed out of the whole vitelline mass, as it is in the whelk, the oyster and the star-fish. The bird, the crocodile and the cuttle-fish resemble each other in the embryo rising out of the yolk, assimilating only a portion, and leaving the rest as an appendage until the period of birth, or for a short time after.

It may be doubted, therefore, if embryology alone is decisive of the question whether homology can be predicated of the alimentary canal in animals of different primary groups or provinces. The armadillo (*Dasypus*) and the woodlouse (*Oniscus*) are good subjects for illustrating this question. In both, the alimentary canal begins at the fore part and terminates at the hind part of the body: in both, an œsophagus precedes a stomach, as this precedes the part of the canal receiving the biliary secretion; in both, the intestine follows to terminate at the vent.

Besides the sameness of function, the homologist, confiding in the characters of connexion and relative position, would retain the names 'alimentary canal,' 'mouth,' 'gullet,' 'stomach,' 'gut,' to express his ideas of the veritable answerable character of the parts compared in *Oniscus* and *Dasypus*: but he who believes embryology alone capable of affording a solid basis for determining homologies*, will infer that the different relations of the yolk and the intestine in the embryos of the vertebrate and articulate

* "Embryology affords further a test for homologies in contradistinction to analogies. It shows that true homologies are limited respectively within the natural boundaries of the great branches of the animal kingdom."—Agassiz, Nat. Hist. of the United States, 4to, 1857, vol. i. p. 86.

animals*, establish that the so-called alimentary canal is an essentially different part in the mammal and the insect.

The almost annular ossified segments of the skin of the armadillo, arranged so as to overlap and allow the body to be contracted into a ball, are, on the basis of connexions and relative position, homologous with the almost annular chitinous segments of the skin of the wood-louse, which present the same arrangement for permitting that insect to roll itself into a ball. But, according to the embryological basis, there can be no true homology between the parts compared; this relation being limited respectively within the natural boundaries of the great branches of the animal kingdom.

The zoologist may learn from the above instances the phase at which the philosophical study and comparison of animal structures has now arrived, and I shall not pursue the disquisition further on the present occasion.

It is significant, however, of the lower value of embryological characters, to note that the great leading divisions of the animal kingdom, based by Cuvier on comparative anatomy, have merely been confirmed by Von Baer's later developmental researches. And so, likewise, with regard to some of the minor modifications of Cuvier's provinces, the true position of the *Cirripedia* was discerned by Straus Durkheim and Macleay, by the light of anatomy, before the discovery of their metamorphoses by Thomson.

If, however, embryology has been over-valued as a test of homology, the study of the development of animals has brought to light most singular and interesting facts, and I now allude more especially to those that have been summed up under the term 'Alternate-generation,' 'Parthenogenesis,' 'Metagenesis,' &c.

John Hunter first enunciated the general proposition (many of the facts being known long before his time), that "the propagation of plants depended on two principles, the one that every part of a vegetable is 'a whole,' so that it is capable of being multiplied as far as it can be divided into distinct parts; the other, that certain of those parts become reproductive organs, and produce fertile seeds." Hunter also remarked that "the first principle operated in many animals which propagate their species by buds or cuttings;" but that, whilst in animals, it prevailed only in "the more imperfect orders," it operated in vegetables "of every degree of perfection." He suggestively remarks, however, that "those degrees are few in comparison with the 'animal,' and that the least perfect 'animal' is probably on a par with the most perfect 'vegetable†.'" Subsequent progress has shown that what seemed 'probable' when Hunter wrote is not exactly true. The special conditions of organisms or living things, which we call 'vegetable' and 'animal,' rise by degrees and diverge from a general organic character or

* "The alimentary canal is formed in a very different way in the embryos of the two types; and it would be as unnatural to identify them, as it would be still to consider gills and lungs as homologous among Vertebrata."—Agassiz, *op. cit.*, p. 86.

† Physiol. Catal., p. 5.

basis: and the degree of progress at which 'animality' can be predicated, is 'on a par' with that at which 'vegetality' can be predicated. Then follow other steps of complexity, by which plants and animals diverge from each other as they rise in the scale of perfection.

The experiments of Trembley on the freshwater polype, those of Spallanzani on the Naiads, and those of Bonnet on the Aphides, had brought to light the phenomena of propagation by fission, and by gemmation or buds, external and internal, in animals, to which Hunter refers. Subsequent research has shown the unexpected extent to which Hunter's first principle of propagation in organic beings prevails in the animal division. But the earliest formal supersession of Harvey's axiom, 'omne vivum ab ovo,' appears to be Hunter's proposition of the dual principle above quoted. Bacon readily accepted, as, indeed, it was congenial with his physiological philosophy, the doctrine current in his day of the spontaneous origin of worms, insects, eels, and other 'creeping things.' But this doctrine receives no countenance from the modification of the Harveian dictum introduced by the great English physiologist of the last century.

The experiments of Redi, Malpighi, and others, had progressively contracted the field to which the 'generatio æquivoca' could with any plausibility be applied. The stronghold of the remaining advocates of that old Egyptian doctrine was the fact of the development of parasitic animals in the flesh, brain and glands of higher animals. But the hypothesis never obtained currency in this country; it was publicly opposed in my 'Hunterian Lectures,' by the fact of the prodigious preparation of fertile eggs in many of the supposed spontaneously developed species; and in then suggesting that the '*Trichina spiralis*' of the human muscular tissue might be the embryo of a larger worm in course of migration, I urged that a particular investigation was needed for each particular species*. Among the most brilliant of recent acquisitions to this part of physiology have been the discoveries which have resulted from such special investigations. Kuchenmeister and Von Siebold have been the chief labourers in this field. I may instance a few of their results.

The 'thread-worms' (*Filariæ*) of certain insects, which present no trace of sexual organs, were supposed to be spontaneously developed in those insects. The little worms were, however, by special and due research, seen to wind their way out of the caterpillars they infested. Von Siebold placed these free *Filariæ* in damp earth, into which they soon bored: in a few weeks he found that the sexual organs were developed in them, and that they laid hundreds of eggs. Early in spring the young worms were hatched and began to creep about. Von Siebold took some young caterpillars of the moth (*Yponomeuta euonymella*), in which were no parasites: he placed them in the soft earth in which the young *Filariæ* had been hatched; and in twenty-four hours most of the caterpillars were infested by the young

* Hunterian Lectures, reported in 'Medical Times.'

thread-worms, which had bored their way through the soft skin into their interior.

The long hair-worm of fresh-waters (*Gordius aquaticus*), vulgarly conceived to be the result of a metamorphosis of the hair of a horse's tail, passes its early life as a parasite in the body of an insect.

But many entozoa acquire their full or sexual development, not as free worms, but within the body of another animal, and of a species distinct from that in which they had passed the early or larval stage of their existence.

The trematode parasite of a water-fowl produces eggs, from each of which is hatched a ciliated infusorial-like young. These young escape into the water, and there swim about by their vibratile cilia, like *Infusoria;* some of them enter the body of a water-snail; but they are merely the locomotive envelope of a differently-shaped smooth-skinned organism, resembling in its simple uniform granular structure a *Gregarina*; and the function of that ciliated envelope was to introduce the *Gregarina* into the body of the water-snail. So introduced, the growth of the gregariniform parasite proceeds, and a progeny is seen to arise in its interior, by the development of several of the contained germ-cells into embryos: it proves, indeed, to be a mere cyst for such, as the infusorial larva had been a cyst for it. The embryos gradually acquire the form of a *Cercaria.* These escape from the cyst, bore their way out of the snail, and disperse themselves as free swimming tadpole-like animalcules in the water. No sexual organs exist in these '*Cercariæ,*' any more than in their animated 'coat' the *Gregarina,* or in their ciliated 'great-coat' the infusorial embryo. After the larval *Cercariæ* have passed some time in the water, first creeping and then swimming about with great restlessness, they either enter directly the body of a water-fowl, or bore their way into some aquatic insect, or they may fail in both these instinctive efforts and remain in the water. In any case they undergo a metamorphosis. The *Cercaria* gathers itself up into a ball and exudes a mucous secretion from its surface, which soon hardens; and, since the worm, inside this mucous mass, turns round without stopping, it invests itself with a kind of egg-shell: during this process the tail is cast off.

Should this process take place within the body of an insect, the encysted *Cercaria* might be introduced into the body of an insectivorous bird or beast. In the act of digestion by the engulpher the body of the insect is destroyed, together with the capsule of the cercarian pupa; but this by virtue of its vitality remains unharmed, and is thus transplanted into a sphere fitted for its further change into a sexual entozoon of the Trematode or 'fluke-worm' order.

Then again commences the strange and complex genetic cycle from the Harveian point—the impregnated ovum.

Three different species of animal may contribute—two are essential—to the successful progress of the ordinary and parthenogenetic processes of propagation manifested by the three distinct forms of Infusory, Gregarina and Cercaria, intervening between the egg and the perfect parasitic fluke-worm.

This instance (a knowledge of which is due chiefly to the researches of Von Siebold) I have thought it requisite to quote, in order to convey some idea to my non-physiological auditors of the singular complexity of powers and arrangements tending to the ultimate right lodgement and well-being of a seemingly insignificant noxious little parasite.

The sum of the recent researches on the generation of the Entozoa teaches that to the success in life of the majority of these internal parasites, two different species of much higher organized animals are subservient; and that these two species stand in the relation of prey and devourer.

The habits of the prey favour the accidental introduction (as when a slug crawls over the droppings of a thrush) of the eggs of the birds' intestinal parasite. These are hatched in the slug. The slug in its turn is devoured by the thrush; but the parasitic passengers are not digested—only the coach is dissolved, and the larvæ, thus set free, find in the warm intestines of the bird the appropriate conditions for their metamorphosis and full development.

In like manner, the *Rhynchobothria* of a cuttle-fish are the larvæ of the *Tetrarhynchus* or four-tentacled tape-worm of a dog-fish. The encysted sexless *Triænophorus* of the liver of the char becomes the free and perfect *Triænophorus* of the gut of the pike. The *Ligula* of a herring becomes a *Tænia* only when introduced into the interior of a cormorant. The bladder-worm (*Cysticercus fasciolaris*) of the mouse's liver becomes the tape-worm (*Tænia crassicollis*) of the cat. The *Cysticercus pisiformis* of the liver of the hare becomes the *Tænia serrata* of the dog and fox.

Dr. Küchenmeister of Zittau first proved, experimentally, by feeding animals with *Cysticerci* (Hydatids of the flesh and glands of herbivorous animals), that they became *Tæniæ* (intestinal tape-worms) in carnivorous animals. The results of these instructive experiments were published in 1851 *. They have been successfully repeated, amplified, and scientifically explained, in regard to every particular and step of the progress, by the indefatigable and accurate Von Siebold †. The part which *Parthenogenesis* plays in the changing scenes of entozoal life is acutely discerned and clearly explained in this work.

Since the time when it was first discovered that plants and animals could propagate in two ways, and that the individual developed from the bud might produce a seed or egg, from which also an individual might spring capable of again budding,—since this alternating mode of generation was observed, as by Chamisso and Sars, in cases where the budding individual differed much in form from the egg-laying one—the subject has been systematized ‡, generalized, with an attempt to explain its

* Gunsburg's Zeitschrift für Klinische Vorträge, 1851, p. 240.

† Ueber die Band- und Blasenwürmer, &c. 8vo. Leipzig, 1854.

‡ Steenstrup (J.), "Ueber den Generationswechsel oder die Fortpflanzung durch abwechselnde Generation," Kopenh. 1842. 8vo.

principle*, and greatly advanced†, especially, and in a highly interesting manner, in Von Siebold's late treatise, entitled "Wahre Parthenogenesis bei Schmetterlingen und Bienen," in which the virgin-production of the male or drone-bee is demonstrated.

Von Siebold, having subjected to the closest microscopic scrutiny and experiment the conclusion to which the practical Bee-master Dzierson had arrived, relative to the cause of Queen-bees with crippled wings producing a swarm exclusively of drones, has demonstrated that the male-bee is produced from an egg which has been subjected to no influence save that of the maternal parent; whilst such egg, if impregnated, would have produced a female or worker-bee.

Von Siebold has established the same most interesting phase of parthenogenesis in certain *Lepidoptera*, e. g. *Solenobia lichenella*, *S. clathrella*, *Psyche helix;* and he calls this phase emphatically 'true parthenogenesis.'

Bonnet's famous experiments on the parthenogenetic Aphides have been repeated and confirmed by myself‡ and others. Hartig§ has shown the same property in the genera *Cynips* and *Apophyllus*, which explains the fact of the appearance of *Cynips lignicola* in vast numbers in the south-west of England during the present and preceding summers, but all of the female sex. The little crustaceans of the genus *Daphne* have long been known to produce agamic eggs. A newly-hatched female isolated in a tumbler will produce a brood of the same sex, whence a second brood will issue, to perhaps the sixth generation. Mr. John Lubbock, in an admirable paper in the 'Philosophical Transactions' for 1857, has repeated the experiments of Jurine, and added many valuable facts. He has pointed out the precise relations between the agamic and ephippial eggs. The young from any one brood of agamic eggs are all of one sex, which usually is female: but in one instance Mr. Lubbock observed that they were all males. His memoir will well repay a careful study. I had previously stated the grounds for concluding that there was no essential distinction between buds and eggs, and for anticipating that every gradation would be found between them: and many steps in that series have been since supplied by Lubbock, Leidy, and Von Siebold.

Gærtner has given an abridged account of experiments, showing that

* Owen, "On Parthenogenesis, or the Successive Production of Procreating Individuals from a single Ovum," 8vo. London, 1849.

Ib. "On Metamorphosis and Metagenesis," 8vo. 1857.

Prosch (V), "Om Parthenogenesis og Generationsvexel," Kiöbenhavn, 1851.

† Lubbock (J.), "An Account of Two Methods of Reproduction in Daphnia," &c., Phil. Trans. 1857, p. 79.

Carus (J. Victor), "Zur näheren Kenntniss des Generationswechsels," 8vo. Leipzig, 1849.

Leuckart (K.), "Ueber Metamorphose ungeschlechtliche Vermehrung, Generationswechsel," Zeitschrift für Wissensch. Zoologie, vol. iii. 1851.

Gegenbaur (U.), "Zur Lehre vom Generationswechsel und der Fortpflanzung bei Medusen und Polypen," 8vo. Würzburg, 1854.

‡ Parthenogenesis.

§ Germar's Zeitschrift, vol. ii. p. 178.

some plants have the power of producing 'agamic' or fertile but unpollenized seeds: e. g. *Zea Mays*, *Cannabis sativa*, *Spinacia oleracea*, *Mercurialis annua*; and if doubt may yet attend the results of the experiments on these and other plants which Gærtner cites, none, I believe, is now entertained by botanists of the germinative power of the seeds, independently of any action of pollen, of the *Cœlobogyne ilicifolia*. This plant, a native of Moreton Bay, Australia, is diœcious like the rest of the order (*Euphorbiaceæ*) to which it belongs. A female plant was sent to the Royal Botanic Gardens at Kew some years ago, where it may now be seen in full vigour; but year after year this pistil-bearing individual has formed its flowers and fertile seeds as perfectly reproductive as if its staminiferous mate was blooming in the next parterre. No male plant has yet, in fact, been introduced.

M. Lehocq has recorded in the 'Comptes Rendus de l'Acad. des Sciences,' Dec. 1856, the same phenomena in *Trinia vulgaris*, *Mercurialis annua*, and some other plants.

The now well-investigated phenomena of parthenogenesis in *Hydrozoa* have resulted in showing, as in the analogous case of *Entozoa*, that animals differing so much in form as to have constituted two distinct orders or classes, are really but two terms of a cycle of metagenetic transformations—the acalephan *Medusa* being the sexual locomotive form of the agamic rooted budding polype, just as the cestoid Tænia is of the cystic Hydatid.

In *Hydrozoa* (Hydroid Polypes or Sertularians) the young are propagated, as in plants, by 'buds, and also, as in most plants, by 'germs' or 'seeds:' these latter are contained in 'germ-sacs' projecting from the outer surface, which is another analogy to the flowering parts of plants. The germ-sac contains either bare-eyed medusæ, or medusoid germs in small closed 'sporosacs.' Both medusæ and medusoids contain either the eggs or the pollen-like zoosperms. The germ-sac may be 'simple' or 'compound,' the latter containing a special organ or process of the 'cænosarc,' from whose sides bud out the sporosacs or medusæ.

The first acquaintance with these marvels excited the hope that we were about to penetrate the mystery of the origin of different species of animals; but as far as observation has yet extended, the cycle of changes is definitely closed. And, since one essential step in the series is the fertilized seed or egg, the Harveian axiom, 'omne vivum ab ovo,' if metagenetic phases be ascribed to one individual, may be still predicated of all organisms which bear the unmistakeable characters of Plants or of Animals.

The closest observations of the subjects of these two kingdoms most favourable to clear insight into the nature of their beginning, accumulate evidence in proof of the essential first step being due to the protoplasmic matter of a germ-cell and sperm-cell; the former pre-existing in the form of a nucleus or protoplast, the latter as a granulose fluid. In flowering plants it is conveyed by the pollen-tube, in animals and many flowerless plants by locomotive spermatozoids.

In regard to lower living things, analogy is but hazardous ground for conclusions. The single-celled organisms, such as many of the so-called animalcules of infusions, which are at a stage of organization too low for a definite transfer to either the vegetable or animal kingdoms, offer a field of observation and experiment which may yet issue in giving us a clearer insight into the development of the organic living cell.

Whether an independent free-moving and assimilating organism, of a grade of structure similar to, and scarcely higher than the 'germ-cell,' may not arise by a collocation of particles, through the operation of a force analogous to that which originally formed the germ-cell in the ovarian stroma, is a question which cannot be answered until every possible care and pains have been applied to its solution.

The changes of form which the representative of a species undergoes in successive agamically propagating individuals are termed the 'metagenesis' of such species. The changes of form which the representative of a species undergoes in a single individual is called the 'metamorphosis.' But this term has practically been restricted to the instances in which the individual, during certain phases of the change, is free and active, as in the grub of the chaffer, or the tadpole of the frog, for example.

In reference to some supposed essential differences in the metamorphoses of insects, it had been suggested that stages answering to those represented by the apodal and acephalous maggot of the *Diptera*, by the hexapod larva of the *Carabi*, and by the hexapod antenniferous larvæ of the *Meloe* were really passed through by the orthopterous insect, before it quitted the egg*.

Mr. Andrew Murray † has recently made known some facts in confirmation of this view. He had received a wooden idol from Africa, behind the ears of which a Blatta had fixed its egg-cases, after which the whole figure had been rudely painted by the natives, and these egg-cases were covered by the paint. No insect could have emerged without breaking through the case and the paint; but both were uninjured. In the egg-cases were discovered,—1st, a grub-like larva in the egg; 2nd, a cocoon in the egg containing the unwinged, imperfectly-developed insect; 3rd, the unwinged, imperfectly-developed insect in the egg, free from the cocoon, and ready to emerge.

Such observations tending to remove supposed exceptions and anomalies, and to illustrate and establish the common law to which they can be reduced, are of the highest value in Natural History.

Microscope.—The microscope is an indispensable instrument in embryological and histological researches, as also in reference to that vast swarm of animalcules which are too minute for ordinary vision. I can here do little more than allude to the systematic direction now given to the application of

* Owen, "On Metamorphosis and Metagenesis," 1851, and "Lectures on Invertebrata," 8vo, 1855, p. 424.

† "On the Metamorphosis of Orthopterous and Hemipterous Insects," Edinb. Phil. Journal, 1858.

the microscope to particular tissues and particular classes, chiefly due, in this country, to the counsels and example of the Microscopical Society of London.

A very interesting application of the microscope has been made to the particles of matter suspended in the atmosphere; and a systematic continuation of such observations by means of glass slides prepared to catch and retain atmospheric atoms, promises to be productive of important results.

We now know that the so-called red-snow of Arctic and Alpine regions is a microscopic single-celled organism which vegetates on the surface of snow.

Cloudy or misty extents of dust-like matter pervading the atmosphere, such as have attracted the attention of travellers in the vast coniferous forests of North America, and have been borne out to sea, have been found to consist of the 'pollen' or fertilizing particles of plants, and have been called 'pollen showers.'

M. Daneste*, submitting to microscopic examination similar dust which fell from a cloud at Shanghai, found that it consisted of spores of a confervoid plant, probably the *Trichodesmium erythræum*, which vegetates in, and imparts its peculiar colour to, the Chinese Sea.

Decks of ships, near the Cape de Verd Islands, have been covered by such so-called 'showers' of impalpable dust, which, by the microscope of Ehrenberg, has been shown to consist of minute organisms, chiefly 'Diatomaceæ.' One sample collected on a ship's deck 500 miles off the coast of Africa, exhibited numerous species of freshwater and marine diatoms bearing a close resemblance to South American forms of those organisms. Ehrenberg has recorded numerous other instances in his paper printed in the 'Berlin Transactions;' but here, as in other exemplary series of observations of the indefatigable microscopist, the conclusions are perhaps not so satisfactory as the well-observed data.

He speculates upon the self-developing power of organisms in the atmosphere, affirms that dust-showers are not to be traced to mineral material from the earth's surface, nor to revolving masses of dust material in space, nor to atmospheric currents simply; but to some general law connected with the atmosphere of our planet, according to which there is a 'self-development' within it of living organisms, which organisms he suspects may have some relation to the periodical meteorolites or aërolites. The advocates of progressive development may see and hail in this the first step in the series of ascending transmutations. The unbiassed observer will be stimulated by the startling hypothesis of the celebrated Berlin Professor to more frequent and regular examinations of atmospheric organisms. Some late examinations of dust-showers clearly show them to have a source which Ehrenberg has denied. Some of my hearers may remember the graphic description by Her Majesty's Envoy to Persia, the Hon. C. A. Murray, of the cloud of impalpable red dust which darkened the air of Bagdad, and filled the city

* Annales des Sciences Naturelles, sér. 4. Botanique, t. i. p. 81.

with a panic. The specimen he collected was examined by my successor at the Royal College of Surgeons, Prof. Quekett; and that experienced microscopist could detect only inorganic particles, such as fine quartz sand, without any trace of Diatomaceæ or other organic matter. Dr. I awson has obtained a similar result from the examination of the material of a shower of moist dust or mud which fell at Corfu in March 1857: it consisted for the most part of minute angular particles of a quartzose sand.

Here, therefore, is a field of observation for the microscopist, which has doubtless most interesting results as the reward of persevering research.

Many 'dust-showers' consist in greater or less proportions of microscopic organisms, but not all. To determine the source of these organisms is the legitimate aim of such researches. It must be remembered, also, that the expression 'spontaneously developed' in the atmosphere, may only mean what is meant when it was formerly applied to the internal parasites of man and animals, viz. ignorance of the true mode of origin. And since persevering observation and experiment, in regard to tape-worms and ascarides, have thrown such new and unexpected light upon their origin and migrations, so the like result may reward similar labours applied to the parasitic 'dust-showers' of the atmosphere.

Microgeology.—The microscopic organisms hitherto observed in the oldest fossiliferous deposits, Silurian Greensands, for instance, are spicula of *Spongiæ*, siliceous *Polycystineæ*, and calcareous *Foraminifera*.

Ehrenberg has discovered that the substance of the greensands in stratified deposits, from the Silurian to the Tertiary periods inclusive, is composed of the casts of the interior of the microscopic shells of *Polycystineæ* and *Foraminifera*. The soundings which have been brought up from various parts of the Atlantic and the Gulf of Mexico, consist chiefly of similar microscopic polythalamous shells, mingled with a greensand composed of casts of *Foraminifera*. Thus the mode in which a deposit was made at the bottom of the deep primeval ocean of the Silurian period, is illustrated by that which the microscope has demonstrated to take place under similar conditions at the present day.

The earliest indubitable evidence of diatoms has been obtained from the Eocene strata; and the forms here determined have been for the most part identified with existing species. Exotic species are not distinguishable from the British; difference of climate seems not to affect or relate to specific difference, and the same exemption from such influence through the minute size and simple structure of the Diatomaceæ, seems to have been the chief condition of their geological longevity as species.

To specify or analyse the labours of the individuals who of late years have contributed to advance zoology by the comprehensive combination of the various kinds of research now felt to be essential to its right progress, would demand a proportion of the present discourse far beyond its proper and allotted limits.

Yet I shall not be deemed invidious if I cite one work as eminently exemplary of the spirit and scope of the investigations needed for the elucidation of any branch of Natural History. That work is the monograph of the Chelonian Reptiles (Tortoises, Terrapenes and Turtles) of the United States of America, published last year at Boston, U.S., by Professor Agassiz.

I cite it, not wholly on account of its intrinsic merits, but also because it affords me the opportunity of expressing, on the part of naturalists, the admiration of, and deep sense of gratitude to, the great and liberal people whose perception of the intrinsic value and dignity of pure science has enabled the distinguished author to enrich zoology by a work unparalleled in the completeness, perfection, and consequent expense of its graphic illustrations. "We had fixed," writes Agassiz, "upon five hundred subscribers as the number necessary to enter upon the publication with safety:—at this moment it stands at twenty-five hundred,—a support such as was never before offered to any scientific man for purely scientific ends, without any reference to government objects or direct practical aims*."

Geographical Distribution of Plants.—Observations of the characters of plants, the record of such observations by the Linnæan and subsequently improved artifices of description, the application of this power to comparison, and deductions from the results of such comparisons,—have led to the recognition of the natural groups or families of the vegetable kingdom, and to a clear scientific comprehension of that great department of living Nature.

This phase of botanical science gives the power of further and more profitable generalizations, such as those teaching the relations between the particular plants and particular localities.

The sum of these relations, forming the Geographical Distribution of Plants, rests, perhaps at present necessarily, on an assumption, viz. that each species has been created, or come into being, but once in time and space; and that its present diffusion is the result of its own law of reproduction, under the diffusive or restrictive influence of external circumstances. These circumstances are chiefly temperature and moisture, dependent on the distance from the source of heat and the obliquity of the sun's rays, modified by altitude above the sea-level, or the degree of rarefaction of the atmosphere, and of the power of the surface to radiate heat. Both latitude and altitude are further modified by currents of air and ocean, which influence the distribution of the heat they have absorbed. Thus large tracts of dry land produce dry and extreme climates, while large expanses of sea produce humid and equable climates. Botany, in short, at this phase becomes intimately related to climatology; and the traveller, the meteorologist, and the naturalist reciprocally aid each other in the acquisition of a knowledge of fruitful general laws. Agriculture affects the geographical distribution of plants, both directly and indirectly. It diffuses plants over a wider area of

* Agassiz, "Monograph on North American Testudinata," 4to, Boston, 1857, Preface, p. viii. vol. i. Of the 2500 Subscribers only 20 are Extra-american.

equal climate, augments their productiveness, and enlarges the limits of their capacity to support different climatal conditions. Agriculture also effects local modifications of climate. The clearance of forests, by diminishing the cooling influence of evaporation from leaves, increases the temperature. When, by the spread of thorough drainage over Britain, the surface-water is at once carried off, instead of remaining on the surface until slowly dispersed by evaporation and atmospheric currents, such prompt removal of the raw material of mist and cloud may be reasonably expected to be attended with a greater average annual amount of solar light and heat.

Certain species of plants require more special physical conditions for health; others more general conditions; and their extent of diffusion varies accordingly. Thus the plants of temperate climates are more widely diffused over the surface of the globe, because they are suited to elevated tracts in tropical latitudes.

There is, however, another law which relates to the original appearance, or creation, of plants, and which has produced different species flourishing under similar physical conditions, in different regions of the globe. Thus the plants of the mountains of South America are of distinct species, and for the most part of distinct genera, from those of Asia. The plants of the temperate latitudes of North America are of distinct species, and some of distinct genera, from those of Europe. The *Cacteæ* of the hot regions of Mexico are represented by the *Euphorbiaceæ* in parts of Africa having a similar climate.

The modes of generalizing the observations on the geographical distribution of indigenous plants are various.

One is by dividing the horizontal range of vegetation into zones, bounded by annual isothermal lines, as, 1, the equatorial; 2, tropical; 3, subtropical; 4, warmer temperate; 5, cooler temperate; 6, subarctic; 7, arctic; 8, polar zones: with temperatures progressively falling from an annual isotherm of 79°·3 Fahr. to one of 36°·5 for the month of July.

Another mode is the classification of plants according to the regions of altitude; as into those of,—1, Palms; 2, Tree-ferns; 3, Myrtles; 4, Evergreens; 5, Deciduous trees; 6, Conifers; 7, Alpine shrubs; 8, Alpine herbs. But the corresponding altitudes in different countries have frequently different, though analogous or representative, species. The presence or otherwise of snow on the mountain-tops also influences the character of the plants at corresponding altitudes. Thus, forests of tall Conifers flourish in the Himalayas at regions of altitude where only stunted specimens of tropical plants are found in the mountains of Sumatra.

A third, and perhaps more truly natural mode of expressing the geographical distribution of plants, is by regions defined by the proportion of plant-species peculiar to them. When one half, at least, of the known species are peculiar to a certain space, it constitutes a 'phytogeographic' region, according to Schouw. In it, also, a fourth part of the genera must be either peculiar, or so predominating as to be comparatively rare in other regions; and the individual families of plants must be either peculiar to, or decidedly predominate in, such region.

So defined, the surface of the earth has been divided into twenty-five regions, of which I may cite as examples that of New Zealand, in which Ferns predominate, together with generic forms, half of which are European, and the rest approximating to Australian, South African, and Antarctic forms; and that of Australia, characterized by its *Eucalypti* and *Epacrides*, chiefly known to us by the researches of the great botanist, Robert Brown, the founder of the 'Geography of Plants.'

Of the heaths, or heath-like shrubs, some genera, *Erica*, or true heath, for example, characterize the Cape of Good Hope and Europe; other genera the Cape and New Holland; others again, as *Epacris*, *Lissanthe*, and *Leucopogon*, are characteristic of Australia.

The vegetable kingdom has been classified into many such physiognomical groups. The latest botanical statistics make 213,280 species; but the best informed botanists believe that we are still acquainted only with a small proportion of existing plants.

Geographical Distribution of Animals.—Organic Life, in its animal form, is much more developed, and more variously, in the sea, than in its vegetable form.

Observations of marine animals and their localities have led to attempts at generalizing the results; and the modes of enunciating these generalizations or laws of geographical distribution are very analogous to those which have been applied to the vegetable kingdom, which is as diversely developed on land as is the animal kingdom in the sea. Certain horizontal areas, or provinces, have been characterized by the entire assemblage of animals and plants constituting their population, of which a considerable proportion is peculiar to each province, and the majority of the species have their areas of maximum development within it.

Of such provinces of Marine Life, that much-lamented, far-seeing, and genial philosopher, Edward Forbes, has provisionally defined 25.

The same physical conditions are associated with a certain similarity between the animals of different provinces. Where those provinces are proximate, such likeness is due to the identity or close affinity of the species; but where the provinces are remote, the resemblance is one of analogy, and species of different genera or families represent each other.

A second mode of expressing the ascertained facts of the geographical distribution of marine animals is by tracts called 'Homoiozoic Belts,' bounded by climatal lines, which are not, however, parallel with lines of latitude, but undulate in subordination to climatal influences of warm or cold oceanic currents, relations of land to water, &c. Of these belts, Professor E. Forbes has defined nine: one equatorial, with four to the north and four to the south, which are mutually representative.

But the most interesting form of expression of the distribution of marine life is that which parallels the perpendicular distribution of plants. Edward Forbes, availing himself of the valuable results of a systematic use of the dredge, first showed that marine animals and plants varied according to the depth at which they lived, in a manner very analogous to the changes in the forms and species of vegetation observed in the ascent of a tropical mountain. He has expressed these facts by defining five bathymetrical zones, or belts of depth, which he calls,—1, Littoral; 2, Circumlittoral; 3, Median; 4, Infra-median; 5, Abyssal.

The life-forms of these zones vary, of course, according to the nature of the sea-bottom; and are modified by those primitive or creative laws that have caused representative species in distant localities under like physical conditions,—species related by analogy.

Very much remains to be observed and studied by Naturalists in different parts of the globe, under the guidance of the generalizations thus sketched out, to the completion of a perfect theory. But in the progress to this, the results cannot fail to be practically most valuable. A shell or a sea-weed, whose relations to depth are thus understood, may afford important information or warning to the navigator. To the geologist the distribution of marine life according to the zones of depth has given the clue to the determination of the depth of the seas in which certain formations have been deposited.

By the light of these laws of geographical distribution we view with quite a new interest the shells, corals, and sea-weeds of our own shores. We trace the regions whence they have been invaded by races not aboriginally belonging to our seas; we obtain indications of irruptions of sea-currents of dates anterior to the present arrangements of land and water. Thus, part of our marine fauna has been traced back to the older pliocene period, part to the somewhat newer period of the red-crag, part to the still more recent glacial period—all these being anterior to the constitution of the 'Celtic Province,' as it is now displayed.

With regard to the class of Fishes, some families, the Sharks (Squaloids), Herrings (Halecoids), and Mackerel-kind (Scomberoids), are cosmopolitan. The Labyrinthodonts are limited to the Indian Ocean; the Goniodonts to the rivers of South America; the *Lepidostei* to those of North America; the *Polypteri* to those of Africa. The fish called *Chaca* is restricted to the Lake Baikal, and the blind '*Amblyopsis*' to the Mammoth cave: just as the Proteus amongst amphibious reptiles is confined to the caverns of Carinthia.

The class of animals to which the restrictive laws of geographical distribution might seem least applicable is that of Birds: their peculiar powers of locomotion, associated in numerous species with migratory habits, might seem to render them independent of every influence save those of climate and of food, which directly affect the conditions of their existence. Yet the long-winged Albatros is never met with north of the equator; nor does the Condor soar above other mountains than the Andes. The geographical range of its European representative, the strong-winged Lammergeyer, is similarly restricted. The Asiatic *Phasianidæ* and *Pavonidæ* are represented by Turkeys (*Meleagris*) in America; by the Guinea-fowl (*Numida, Agelastus, Phasidus*) in Africa; and by the *Megapodidæ*, or Mound-birds, in Australia. Several genera of Finches are peculiar to the Galapagos Islands; the richly and fantastically ornate Birds of Paradise are restricted to New Guinea and some neighbouring isles. Mr. Sclater, who has contributed the latest summary of facts on the distribution of Birds, reckons 17 families as peculiar to America, and 16 families as peculiar to Europe, Asia, and Africa. Some species have a singularly restricted locality, as, the Red-grouse (*Tetrao scoticus*) to the British Isles; the Owl-parrot (*Nestor productus*) to Philip Island, a small spot near New Zealand.

When birds have wings too short for flight, we marvel less at their restricted range; and particular genera of brevipennate birds have their peculiar continents or islands. The long- and strong-limbed Ostrich courses over the whole continent of Africa and conterminous Arabia. The genus of three-toed Ostriches (*Rhea*) is similarly restricted to South America. The Emeu (*Dromaius*) has Australia assigned to it. The continent of the Cassowary (*Casuarius*) has been broken up into islands including and extending from the south-eastern peninsula of Asia to New Guinea and New Britain. The singular nocturnal wingless Kivi (*Apteryx*) is peculiar to the islands of New Zealand.

Other species and genera, which seem to be, like the *Apteryx*, as it were mocked with feathers and rudiments of wings, have wholly ceased to exist within the memory of man in the islands to which they also were respectively restricted. The Dodo (*Didus ineptus*) of the Mauritius, and the Solitaire (*Pezophaps solitaria*) are instances.

In New Zealand also there existed, within the memory of the Maori ancestry, huge birds having their nearest affinities to the still existing *Apteryx* of that island, but generically distinct from that and all other known birds. I have proposed the name of *Dinornis* for this now extinct genus, of which more than a dozen well-defined species have come to my knowledge, all peculiar to New Zealand and the last-discovered the strangest, by reason of the elephantine proportions of its feet.

A tridactyle wingless bird of another genus, *Æpyornis*, second only to the gigantic *Dinornis* in size, appears to have also recently become extinct—if it be extinct—in the Island of Madagascar. The egg of this bird, which may have suggested to the Arabian voyagers attaining Madagascar from the Red Sea the idea of the Roc of their romances, would hold the contents of 6 eggs of the Ostrich, 16 eggs of the Cassowary, and 148 eggs of the common Fowl.

The laws of geographical distribution, as affecting mammalian life, have been reduced to great exactness by observations continued since the time of Buffon, who first began to generalize, just a century ago, in that way, noting the peculiarities of the species of South American animals *. The most important extension of this branch of zoology has been due to recent researches and discoveries of extinct species of the class Mammalia; and it is chiefly in relation to the modifications of zoological ideas produced by palæontology that a few brief remarks will here be made.

The Quadrumana, or order of Apes, Monkeys, and Lemurs, consist of three chief divisions—Catarhines, Platyrhines, and Strepsirhines. The first family is peculiar to the 'Old World;' the second to South America; the third has the majority of its species, and its chief genus (*Lemur*), exclusively in Madagascar. Out of 26 known species of *Lemuridæ*, only 6 are Asiatic and 3 are African.

The Catarhine monkeys include the Macaques, most of which are Asiatic, a few are African, and one European; the Cercopitheques, most of which are African, and a few Asiatic; and other genera which characterize one or other continent exclusively. Thus the true Baboons (*Papio*) are African, as are the thumbless Monkeys (*Colobus*) and the Chimpanzees (*Troglodytes*). The Semnopitheques, Gibbons, and Orangs are peculiarly Asiatic. Palæontology has shown that a Macaque, a Gibbon, and an Orang existed during the older tertiary times in Europe; and that a Semnopithecus existed in miocene times in India. But all the fossil remains of Quadrumana in the Old World belong to the family *Catarhina*, which is still exclusively confined to that great division of dry land. The tail-less Macaque (*Inuus silvanus*) of Gibraltar may have existed in that part of the Old World before Europe was separated by the Straits of Gibraltar from Africa. Fossil remains of Quadrumana have been discovered in South America; they indicate Platyrhine forms: a species, for example, allied to the Howlers (*Mycetes*), but larger than any now known to exist, has left its remains in Brazil.

Whilst adverting to the geographical distribution of Quadrumana, I would contrast the peculiarly limited range of the Orangs and Chimpanzees with the cosmopolitan powers of mankind. The two species of Orang (*Pithecus*) are confined to Borneo and Sumatra; the two species of Chimpanzee (*Troglodytes*) are limited to an intertropical tract of the western part of Africa. They appear to be inexorably bound by climatal influences regulating the assemblage of certain trees and the production of certain fruits. With all our care, in regard to choice of food, clothing, and contrivances for artificially maintaining the chief physical conditions of their existence, the healthiest specimens of Orang or Chimpanzee, brought over in the vigour of youth, perish within a period never exceeding three years, and usually much shorter, in our climate. By what metamorphoses, we may ask, has the

* The first enunciation of the principle of Geographical Distribution merits reproduction. Buffon was treating of the carnivorous animal which travellers in South America had called the 'Lion':—"Le *puma* n'est point un lion, tirant son origine des lions de l'ancien continent; c'est un animal particulier à l'Amérique, comme le sont aussi la plupart des animaux de ce nouveau continent."—Tom. ix. p. 13, 1758.

alleged humanized Chimpanzee or Orang been brought to endure all climates? The advocates of 'transmutation' have failed to explain them. Certain it is that those physical differences in cerebral, dental, and osteological structure, which place, in my estimate of them, the genus *Homo* in a distinct group of the mammalian class, zoologically of higher value than the 'order,' are associated with equally contrasted powers of endurance of different climates, whereby Man has become a denizen of every part of the globe from the torrid to the arctic zones.

Climate rigidly limits the range of the Quadrumana latitudinally: creational and geographical causes limit their range in longitude. Distinct genera represent each other in the same latitudes of the New and Old Worlds; and also, in a great degree, in Africa and Asia. But the development of an Orang out of a Chimpanzee, or reciprocally, is physiologically inconceivable,

The order Ruminantia is principally represented by Old World species, of which 162 have been defined; whilst only 24 species have been discovered in the New World, and none in Australia, New Guinea, New Zealand, or the Polynesian Isles.

The Camelopard is now peculiar to Africa; the Musk-deer to Africa and Asia: out of about 50 defined species of Antelope, only one is known in America, and none in the central and southern divisions of the New World. The Bison of North America is distinct from the Bison of Europe. The Musk-ox alone, peculiar for its limitation to high northern latitudes, roams over the arctic coasts of both Asia and America. The Deer-tribe are more widely distributed. The Camels and Dromedaries of the Old World are represented by the Llamas and Vicugnas of the New. As, in regard to a former (tertiary) zoological period, the fossil *Camelidæ* of Asia are of the genus *Camelus*, so those of America are of the genus *Auchenia*. This geographical restriction ruled prior to any evidence of man's existence.

Palæontology has expanded our knowledge of the range of the Giraffe: during miocene or old pliocene periods, species of *Camelopardalis* roamed in Asia and Europe. Passing to the non-ruminant Artiodactyles, geology has also taught us that the Hippopotamus was not always confined, as now, to African rivers, but bathed, during pliocene times, in those of Asia and Europe. But no evidence has yet been had that the Giraffe or Hippopotamus were ever other than Old World forms of *Ungulata*.

With respect to the Hog-tribe, we find that the true Swine (*Sus*) of the Old World are represented by Peccaries (*Dicotyles*) in the New; and geology has recently shown that tertiary species of *Dicotyles* existed in North as well as South America. But no true *Sus* has been found fossil in either division of the New World, nor has a *Dicotyles* been found fossil in the Old World of the geographer. *Phacochœrus* (Wart-hogs) is a genus of the Hog-tribe at present peculiar to Africa.

The Rhinoceros is a genus now represented only in Asia and Africa; the species being distinct in the two continents. The islands of Java and of

Sumatra have each their peculiar species; that of the latter being two-horned, as all the African Rhinoceroses are. Three or more species of two-horned Rhinoceros formerly inhabited Europe—one of them warmly clad, for a cold climate; but no fossil remains of the genus have been met with save in the Old World of the geographer. One of the earliest forms of European Rhinoceros was devoid of the nasal weapon.

Geology gives a wider range to the Horse and Elephant kinds than was cognizant to the student of living species only. The existing *Equidæ* and *Elephantidæ* properly belong to the Old World; and the Elephants are limited to Asia and Africa, the species of the two continents being quite distinct. The horse, as Buffon remarked, carried terror to the eye of the indigenous Americans, viewing the animal for the first time, as it proudly bore their Spanish conqueror. But a species of *Equus* coexisted with the *Megatherium* and *Megalonyx* in both South and North America, and perished apparently with them, before the human period.

Elephants are dependent chiefly upon trees for food. One species now finds conditions of existence in the rich forests of tropical Asia; and a second species in those of tropical Africa. Why, we may ask, should not a third be living at the expense of the still more luxuriant vegetation watered by the Oronooko, the Essequibo, the Amazon, and the La Plata, in tropical America? Geology tells us that at least two kinds of Elephant (*Mastodon Andium* and *Mast. Humboldtii*) formerly did derive their subsistence, along with the great Megatherioid beasts, from that abundant source. Nay more; at least two other kinds of Elephant (*Mastodon ohioticus* and *Elephas texianus*) existed in the warm and temperate latitudes of North America. Twice as many species of Mastodon and Elephant, distinct from all the others, roamed in pliocene times in the same latitudes of Europe. At a later or pleistocene period, a huge elephant, clothed with wool and hair, obtained its food from hardy trees, such as now grow in the 65th degree of north latitude; and abundant remains of this *Elephas primigenius* (as it has been prematurely called, since it was the last of our British elephants) have been found in temperate and high northern latitudes in Europe, Asia, and America. This, like other Arctic animals, was peculiar in its family for its longitudinal range. The Musk Buffalo was its contemporary in England and Europe, and still lingers in the northernmost parts of America.

I have received evidences of Elephantine species from China and Australia, proving the proboscidian pachyderms to have been the most cosmopolitan of hoofed herbivorous quadrupeds.

We may infer that the general growth of large forests, and the absence of deadly enemies, were the main conditions of the former existence of Elephantine animals over every part of the globe. We have the most pregnant proof of the importance of Palæontology in rectifying and expanding ideas deduced from recent Zoology of the geographical limits of particular forms of animals, by the results of its application to the proboscidian or Elephantine family. But such retrospective views of life in remote periods in many important instances confirm the zoologist's deductions of the originally restricted range of particular forms of mammalian life. This is the case with respect to that singular group of quadrupeds forming the Order Bruta, Linn., or Edentata, Cuv. If a zoological province be defined by the proportion of genera and species peculiar to it, South America must be assigned as such province for the *Bruta*; three out of five of the genera, and a much larger proportion of the species, being peculiar to that continent. The Sloths (*Bradypus*), the Anteaters (*Myrmecophaga*), and the Armadillos (*Dasypus*), are the South American genera, or rather families, of *Bruta* referred to. The scaly Anteaters or Pangolins (*Manis*) are represented by long-tailed species in Africa, and shorter-tailed ones in Asia. The *Orycteropus* is represented by a single species in South Africa.

Fossil remains of the order *Bruta* have been discovered in tertiary beds in Europe and in America. The European fossil was a large Pangolin, and the discovery shows the natural extent of that province, now imperfectly divided into Europe, Asia, and Africa, to which the *Manis*-form of *Bruta* is and has been peculiar.

Geology also extends the geographical range of the Sloths and Armadillos from South to North America; but the deductions from recent rich discoveries of huge terrestrial forms of Sloth, of gigantic Armadillos, and large Anteaters, go to establish the fact that these peculiar families of the order *Bruta* have ever been, as they are now, peculiar to America; that several genera, including the largest species, have perished; and that the range of their still existing diminutive representatives has been reduced to the southern division of the 'New World.'

In no other region of the globe than America—that to which the Sloths, Anteaters, and Armadillos are now peculiar—has any fossil relic of an animal of those families been found: and if it be objected to this evidence of the primeval limitation of those families to America, that it is chiefly 'negative,' I would remark, that bones of the Megatherium are as likely to catch the eye as those of the Elephant; and would ask, if Megatherioids had co-existed with Elephants in other continents, as Elephants did with them in America, why have not their remains been found elsewhere? The positive and abundant evidence, however, of the remains of gigantic Sloths and Armadillos in South America is most conclusive of the original location of these unmigratory beasts in the New World.

Australia, which in extent of dry land merits to be regarded as a fifth continent, has a more restricted and peculiar character of aboriginal mammalian population than South America. It is emphatically the 'province' of those quadrupeds the females of which are provided with a pouch for the transport and protection of their prematurely born young.

One genus of *Marsupialia* (*Didelphys* or Opossums, properly so called) is peculiar to America, and is there the sole representative of the order. A small Kangaroo, and a few Phalangers, exist in islands that link the Malayan Archipelago with the Australian world. All the other marsupial genera, indeed every known genus save *Didelphys*, are found in Australasia, comprising New Guinea, Australia, and Tasmania.

The Kangaroos, Potoroos, Wombats, Koalas, Phalangers, Petaurists, Dasyures, and marsupial quadrupeds of insectivorous and carnivorous habits, distinguished only by scientific names, here perform the parts assigned to non-marsupial Mammalia in the Old World. No existing marsupial quadruped has been found native in continental Asia, in Africa, or in Europe.

Of the Australasian marsupials the species of New Guinea are distinct, and some of them subgenerically, from those of Australia proper.

Certain genera, as *Tarsipes*, *Chœropus*, *Phascolarctus*, are peculiar to Australia; other genera, as *Thylacinus* and *Sarcophilus*, the largest and most destructive of carnivorous marsupials, are peculiar to Tasmania.

No marsupial fossil has been found in the pliocene or pleistocene deposits of Europe, Asia, or Africa. In America, only representatives occur of the peculiarly American genus *Didelphys*. In the formations of these recent tertiary periods, and in the limestone caverns, of Australia, abundance of mammalian fossils have been found, and, with the exception of a single tooth of a Mastodon, every one of them has proved to be a marsupial species. Many belong to the genus of Kangaroos (*Macropus*), some to that of Potoroos (*Hypsiprymnus*); a few to the Wombats (*Phascolomys*), Dasyures (*Dasyurus*), and other existing genera. Some of these fossils have shown that the *Thylacinus* and *Sarcophilus* formerly inhabited Australia as well as Tasmania. Others exhibit the carnivorous or Dasyurine modification of the marsupial type in species equalling the Leopard and the Lion in size; and the latter with modifications of the carnassial teeth of generic value. We now know that there once existed in Australia species of Wombat equalling the Tapir in stature; and species most nearly allied to *Macropus*, but with characters of *Phascolomys* and *Phascolarctus* combined, which rivalled the Ox and Rhinoceros in bulk. The skull of the *Nototherium* presents the strangest proportions and features hitherto seen in the mammalian class: that of the *Diprotodon* is 3 feet in length, and combines the scalpriform incisors of the Wombat with the double-ridged molars of the Kangaroo.

The sum of all the evidence from the fossil world in Australia proves its mammalian population to have been essentially the same in pleistocene, if not pliocene times, as now; only represented, as the Edentate mammals in South America were then represented, by more numerous genera, and much more gigantic species, than now exist.

But geology has revealed more important and unexpected facts relative to the marsupial type of quadrupeds.

In the miocene and eocene tertiary deposits, marsupial fossils of the American genus *Didelphys* have been found, both in France and England; and they are associated with Tapirs like that of America. In a more ancient geological period, remains of marsupials, some insectivorous, as *Spalacotherium* and *Triconodon*, others with teeth like the peculiar premolars in the Australian genus *Hypsiprymnus*, have been found in the upper oolite of the Isle of Purbeck*. In the lower oolite at Stonesfield, Oxfordshire, marsupial remains have been found having their nearest living representatives in the Australian genera *Myrmecobius* and *Dasyurus*.

Thus, it would seem, that the deeper we penetrate the earth, or, in other words, the further we recede in time, the more completely are we absolved from the present laws of geographical distribution. In comparing the mammalian fossils found in British pleistocene and pliocene beds, we have often to travel to Asia or Africa for their homologues. In the miocene and eocene strata some fossils occur which compel us to go to America for the nearest representatives. To match the mammalian remains from the English oolitic formations, we must bring species from the Antipodes.

These are truly most suggestive facts, unrecognized until science looked abroad upon the world. If the present laws of geographical distribution depend, in an important degree, upon the present configuration and position of continents and islands, what a total change in the geographical character of the earth's surface must have taken place since the 'Stonesfield slate' was deposited in what now forms the county of Oxfordshire!

These and the like considerations from the modifications of geographical distribution of particular forms or groups of animals warn us how inadequate must be the phenomena connected with the present distribution of land and sea to guide to the determination of the primary ontological divisions of the earth's surface. Some of the latest contributions to this most interesting branch of Natural History have been the result of endeavours to determine whether, and how many, distinct creations of plants and animals have taken place. But, I would submit, that the discovery of two portions of the globe, of which the respective Faunæ and Floræ are different, by no means affords the requisite basis for concluding as to distinct acts of creation.

Such conclusion is associated, perhaps unconsciously, with the idea of the historical date of creative acts: it presupposes that the portion of the globe so investigated by the botanist and zoologist has been a separate and primitive creation,—that its geographical limits and features are still in the main what they were when the creative fiat went forth.

But Geology has demonstrated that such is by no means the case with respect to the portions of dry land now termed continents and islands. The incalculable vistas of time past into which the same science has thrown light are also shown to have been periods during which the relative positions of land and sea have been ever changing.

Already the directions, and to a certain extent the forms of the submerged tracts that once joined what now are islands to continents, and which once united now separate or nearly disjoined continents by broad tracts of conti-

* These fossils are due to the researches of Messrs. Brodie and Beckles.

nuity, begin to be laid down in geological maps, addressing to the eye such successive and gradually progressive alterations of the earth's surface.

These phenomena shake our confidence in the conclusion that the Apteryx of New Zealand and the Red-grouse of England were distinct creations in and for those islands respectively. Always, also, it may be well to bear in mind that by the word 'creation,' the zoologist means 'a process he knows not what.' Science has not yet ascertained the secondary causes that operated when "the earth brought forth grass and herb yielding seed after its kind," and when "the waters brought forth abundantly the moving creature that hath life." And supposing both the fact and the whole process of the so-called 'spontaneous generation' of a fruit-bearing tree, or of a fish, were scientifically demonstrated, we should still retain as strongly the idea, which is the chief of the 'mode' or 'group of ideas' we call 'creation,' viz. that the process was ordained by and had originated from an all-wise and powerful First Cause of all things.

When, therefore, the present peculiar relation of the Red-grouse (*Tetrao scoticus*) to Britian and Ireland—and I cite it as one of a large class of instances in Geographical Zoology—is enumerated by the zoologist as evidence of a distinct creation of the bird in and for such islands, he chiefly expresses that he knows not how the Red-grouse came to be there, and there exclusively; signifying also, by this mode of expressing such ignorance, his belief that both the bird and the islands owed their origin to a great first Creative Cause.

And this analysis of the real meaning of the phrase 'distinct creation' has led me to suggest whether, in aiming to define the primary zoological provinces of the globe, we may not be trenching upon a province of knowledge beyond our present capacities; at least in the judgment of Lord Bacon, commenting upon man's efforts to pierce into the 'dead beginnings of things.'

This at least is certain, that, being aware of former operations requiring to be well understood before we can draw conclusions as to other facts related to the unknown operations, one writes to no purpose in affirming conclusions without such preliminary knowledge.

Thus, the changing level of the land part of the earth's crust, throughout geological time, leads to the recognition of the present shape and size of continents and islands as being recent and temporary.

We feel that there have been phenomena attending, for example, the actual flow of continuous ocean between Ireland and Newfoundland, the nature and succession of which should be known in order to enable us to comprehend the causes or conditions of the present differences between the Flora and Fauna of those islands respectively: and so of every other part of dry land now circumscribed by sea.

All affirmations as to the time, place, and kind of origin of the organisms of a so circumscribed land, in the absence of a knowledge of the causes and conditions of such circumscription, must be guess-work.

It is a part of sound knowledge to be able to recognize the subjects regarding which we have not, at present, the basis of true assertion.

On the few occasions in which I have been led to offer observations on the probable cause of the extinction of species, the chief weight has been given to those gradual changes in the conditions of a country affecting the due supply in sustenance to animals in a state of nature, I have also pointed out the characters in the animals themselves calculated to render them most obnoxious to such extirpating influences; and on one occasion* I have applied the remarks to the explanation of so many of the larger species of particular groups of animals having become extinct, whilst smaller species of equal antiquity have remained.

In proportion to its bulk is the dificulty of the contest which, as a living organized whole, the individual of such species has to maintain against the surrounding agencies that are ever tending to dissolve the vital bond and subjugate the living matter to the ordinary chemical and physical forces. Any changes, therefore, in such external agencies as a species may have been originally adapted to exist in will militate against that existence in a degree proportionate, perhaps in a geometrical ratio, to the bulk of the species. If a dry season be gradually prolonged, the large mammal will suffer from the drought sooner than the small one; if such alteration of climate affect the quantity of vegetable food, the bulky Herbivore will first feel the effects of stinted nourishment; if new enemies are introduced, the large and conspicuous quadruped or bird will fall a prey, whilst the smaller species conceal themselves and escape. Smaller animals are usually, also, more prolific than larger ones.

"The actual presence, therefore, of small species of animals in countries where larger species of the same natural families formerly exisied, is not the consequence of any gradual diminution of the size of such species, but is the result of circumstances, which may be illustrated by the fable of the 'Oak and the Reed;' the smaller and feebler animals have bent and accommodated themselves to changes which have destroyed the larger species."

Accepting this explanation of the extirpation of species as true, Mr. Wallace† has recently applied it to the extirpation of varieties; and, assuming, as is probable, that varieties do arise in a wild species, he shows how such deviations from type may either tend to the destruction of a variety, or to adapt a variety to some changes in surrounding conditions, under which it is better calculated to exist, than the type-form from which it deviated.

No doubt the type-form of any species is that which is best adapted to the conditions under which such species at the time exists; and as long as those conditions remain unchanged, so long will the type remain; all varieties departing therefrom being in the same ratio less adapted to the environing conditions of existence. But, if those conditions change, then

* On the Genus *Dinornis* (part iv.), Zool. Trans. vol. iv. p. 15 (February 1850).

† Proceedings of the Linnean Society, August 1858, p. 57.

the variety of the species at an antecedent date and state of things will become the type-form of the species at a later date, and in an altered state of things.

Mr. Charles Darwin had previously to Mr. Wallace illustrated this principle by ingenious suppositions, of which I select the following:—"To give an imaginary example from changes in progress on an island:—let the organization of a canine animal which preyed chiefly on rabbits, but sometimes on hares, become slightly plastic; let these same changes cause the number of rabbits very slowly to decrease, and the number of hares to increase; the effect of this would be that the fox or dog would be driven to try to catch more hares: his organization, however, being slightly plastic, those individuals with the lightest forms, longest limbs, and best eyesight, let the difference be ever so small, would be slightly favoured, and would tend to live longer, and to survive during that time of the year when food was scarcest; they would also rear more young, which would tend to inherit these slight peculiarities. The less fleet ones would be rigidly destroyed. I can see no more reason to doubt that these causes in a thousand generations would produce a marked effect, and adapt the form of the fox or dog to the catching of hares instead of rabbits, than that greyhounds can be improved by selection and careful breeding*."

Observation of animals in a state of nature is required to show their degree of plasticity, or the extent to which varieties do arise: whereby grounds may be had for judging of the probability of the elastic ligaments and joint-structures of a feline foot, for example, being superinduced upon the more simple structure of the toe with the non-retractile claw, according to the principle of a succession of varieties in time†.

Observation of fossil remains is also still needed to make known the antetypes, in which varieties, analogous to the observed ones in existing species, might have occurred, so as to give rise ultimately to such extreme forms as the Giraffe for example‡.

This application of palæontology has always been felt by myself to be so important that I have never omitted a proper opportunity for impressing the results of observations showing the "more generalized structures" of extinct as compared with recent forms of mammalia.

But, in pointing out how local changes might affect large quadrupeds, I

* Proceedings of the Linnean Society, August 1858, p. 49.

† "The powerful retractile talons of the falcon- and the cat-tribes have not been produced or increased by the volition of those animals; but among the different varieties which occurred in the earlier and less organized forms of these groups, *those always survived longest which had the greatest facilities for seizing their prey*."—Wallace, p. 61.

‡ "Neither did the giraffe acquire its long neck by desiring to reach the foliage of the more lofty shrubs, and constantly stretching its neck for the purpose; but because any varieties which occurred among its antetypes with a longer neck than usual *at once secured a fresh range of pasture over the same ground as their shorter-necked companions, and on the first scarcity of food were thereby enabled to outlive them*."—Ib. p. 61.

have refrained from speculating on dwarf-varieties surviving such influences as being the origin of existing representatives of extinct giants. A small sloth coexisted with the Megatherium, a small armadillo with the Glyptodon, the Apteryx with the Dinornis.

The aboriginal laws of geographical distribution of plants and animals have been modified from of old by geological and the concomitant climatal changes; but they have been much more disturbed by man since his introduction upon the globe.

The serviceable plants and animals which he has carried with him in his migrations have flourished and multiplied in lands the most remote from the habitats of the aboriginal species. Man has, also, been the most potent and intelligible cause of the extirpation of species within historic times.

He alone, with one of the beasts which he has domesticated—the dog—is truly cosmopolitan. The human species is represented by a few well-marked varieties; and there is a certain amount of correspondence between their localities and general zoological provinces: thus the Australian variety of man is as well-marked and circumscribed as the Australian fauna generally; the Papuans of New Guinea present the same difference from, with degree of affinity to, the Australians, as we find in comparing the respective faunæ of Papua and Australia. But, with regard to the alleged conformity between the geographical distribution of man and animals, which has of late been systematically enunciated, and made the basis of deductions as to the origin and distinction of the human varieties, I would submit the following remarks as affecting the system referred to*.

Using Blumenbach's term in the sense of the later terms 'Indo-European' and 'Aryan,' we find the 'Caucasian' race extended from Iceland to the mouth of the Ganges. There is no corresponding distinction in the animals and plants of the Europæo-Asiatic continent, which is bisected by the oblique line dividing the Mongolian from the Caucasian varieties of mankind. The Persian fauna extends into Tartary; the Himalayan into Thibet.

As two primary varieties of mankind exist in one great zoological province in the Old World, so a third great variety extends over at least two zoological provinces in the New World. All authors divide the North American or 'Nearctic' from the South American or 'Neotropic' region, whatever class of organic life they may treat of geographically; but the red or copper-coloured American is the same, physically and linguistically, to the extent of the characteristics of a primary race, from the 60th degree of north latitude to the 53rd degree of south latitude.

The Lapps of Arctic Europe differ linguistically and physically, as a race, from the Norwegians and Swedes: the zoological province is essentially one. As such it extends over the same parallels of latitude in America, where the Mongolian Esquimaux and the American Chippawas inhabit.

* Agassiz, in Gliddon and Nott's 'Types of Mankind,' 1854; and 'Indigenous Races of the Earth,' 1857.

The Hottentots and Caffres are more distinct, linguistically and physically, than the former are from equatorial Negroes, or the latter from the Nubians; yet they both inhabit one well-marked zoological province, South Africa.

Two varieties of mankind—the Papuan and Malayan—inhabit Borneo and other islands at the eastern part of the Indian Archipelago; these islands forming one and the same zoological and botanical province.

Not less than twenty colours have been found requisite to indicate in a map of the British Islands the different varieties and sub-varieties of the human race that have contributed to its miscellaneous population.

Other facts of the same kind might be cited, affecting the conformity of the distribution of man with that of the lower animals and plants, as absolutely enunciated in some recent works. Nor can we be surprised to find that the migratory instincts of the human species, with the peculiar endowment of adaptiveness to all climates, should have produced modifications in geographical distribution to which the lower forms of living nature have not been subject. It is only since man began to exercise his privilege and power, that the geographical laws in regard to the lower animals of existing species have begun to be blotted out.

Ethnology is a wide and fertile subject, and I should be led far beyond the limits of an inaugural discourse were I to indulge in an historical sketch of its progress. But I may advert to the uniform testimony of different witnesses—to the concurrence of distinct species of evidence—as to the much higher antiquity of the human race, than has been assigned it in historical and genealogical records.

Mr. Leonard Horner sagaciously discerned the value of the phenomena of the annual sedimentary deposits of the Nile in Egypt as a test of the lapse of time during which that most recent and still operating geological dynamic had been in progress. In two memoirs communicated to the Royal Society in 1855 and 1858, the results of ninety-five vertical borings through the alluvium thus formed are recorded.

The Nile sediment at the lowest depth reached is very similar in composition to that of the present day. In the lowest part of the boring of the sediment at the colossal statue in Memphis, at a depth of 39 feet from the surface of the ground, the boring-instrument is reported to have brought up a piece of pottery. This Mr. Horner infers to be a record of the existence of man 13,371 years before A.D. 1854; "of man, moreover, in a state of civilization, so far, at least, as to be able to fashion clay into vessels, and to know how to harden them by the action of a strong heat*."

Prof. Max Müller† has opened out a similar vista into the remote past of the history of the human race by the perception and application of analogies in the formation of modern and ancient, of living and dead languages.

* Proceedings of the Royal Society, Feb. 11, 1858, vol. ix. p. 128–134.

† 'Oxford Essays,' 1857.

From the relations traceable between the six Romance dialects, Italian, Wallachian, Rhœtian, Spanish, Portuguese, and French, an antecedent common 'mother-tongue' might be inferred, and consequently the existence of a race anterior to the modern Italians, Spanish, French, &c., with conclusions as to the lapse of time requisite for such divisions and migrations of the primitive stock, and for the modifications which the mother-language had undergone. History and preserved writings show that such common mother-race and language have existed in the Roman people and the Latin tongue.

But Latin, like the equally 'dead' language Greek, with Sanscrit, Lithuanian, Zend, and the Gothic, Slavonic, and Celtic tongues, can be similarly shown to be modifications of one antecedent common language; whence is to be inferred an antecedent race of men, and a lapse of time sufficient for their migration over a track extending from Iceland in the north-west to India in the south-east, and for all the above-named modifications to have been established in the common mother 'Arian' tongue.

The study of the animal kingdom has its practical results of national importance in relation to sources of food and beasts of traction and burden. Acts of Parliament relating to Fisheries, in order to realize their aims, must be based on physiological and zoological data. Animal physiology, the most important ground of successful medicine and surgery, is closely bound up with the right progress of zoology, of which, indeed, with zootomy, it is a branch. The great instrument of zoological science, as Lord Bacon points out, is a Museum of Natural History.

Every civilized state in Europe possesses such a Museum. That of England has been progressively developed to the extent which the restrictive circumstances under which it originated have allowed. The public is now fully aware, by the reports that have been published by Parliament, by representations to Government, and by articles in Reviews and other Periodicals, of the present condition of the National Museum of Natural History and of its most pressing requirements.

Of them the most pressing, and the one essential to rendering the collections worthy of this great empire, is 'space.' Our colonies include parts of the earth where the forms of plants and animals are the most strange. No empire in the world had ever so wide a range for the collection of the various forms of animal life as Great Britain. Never was there so much energy and intelligence displayed in the capture and transmission of exotic animals by the enterprising traveller in unknown lands and by the hardy settler in remote colonies, as by those who start from their native shores of Britain. Foreign Naturalists consequently visit England anticipating to find in her capital and in her National Museum the richest and most varied materials for their comparisons and deductions. And they ought to be in a state pre-eminently conducive to the advancement of a philosophical zoology, and on a scale commensurate with the greatness of the nation and the peculiar national facilities for such perfection.

But, in order to receive and to display zoological specimens, space must be had; and not merely space for display, but for orderly display: the galleries should bear relation in size and form with the nature of the classes respectively occupying them. They should be such "as to enable the student or intelligent visitor to discern the extent of the class, and to trace the kind and order of the variations which have been superinduced upon its common or fundamental characters." In the British Museum one gallery permits this to be done in regard to the class of Birds. "To show how the mammalian type is progressively modified and raised from the form of the fish or lizard to that of man; to illustrate the gradations by which one order merges into another; to impart to the visitor, by the arts of arrangement and juxtaposition, a knowledge of his own class akin to that which he derives from the collection of birds, would require a corresponding Mammalian Gallery*."

The same is to be said of the classes of Reptiles and Fishes, and of the Molluscous, Articulate, and Radiate Provinces.

An osteological collection is as indispensable to the illustration of the Vertebrata as a conchological one is to that of the Mollusca. Nor should the size of any of the skeletons be a bar to the obtainment of adequate space for the Osteological Collection in the National Museum of Natural History. The very fact of the Whales being the largest animals that now exist, or have at any period lived upon the earth, is that which makes it more imperative to illustrate the fact and gratify the natural interest of the public by the adequate and convenient exhibition of their skeletons.

In like manner, in the Palæontological collections or galleries of Fossil remains, the restoration of every extinct species, however bulky, should be carried out where practicable.

The locality of such adequately-sized Museum concerns the administrator and the public convenience. Reasons for its association with Ethnological Antiquities and the National Library have been assigned in a memorial to H. M. Government, and by the Deputation of cultivators of Science to the Chancellor of the Exchequer, and these reasons have been commented on in a late Number of the 'Quarterly Review.'

I am most concerned in advocating the pressing necessity of adequate space for the National Museum of Natural History, wherever administrative wisdom may see fit to locate it. And, wherever that Museum may ultimately stand, it is the duty of the Representative of Associated British Science here to urge that the Curator of each class of animals should have assigned to him the charge of delivering a public course of lectures on the characters, principles of classification, habits, instincts, and economical uses of such class.

* "Report to the Trustees of the British Museum from the Superintendent of the Natural History Departments, 7th January, 1857," Parliamentary printed Paper, 379, p. 23 (1858).

The most elaborate and beautiful of created things—those manifesting life—have much to teach—much that comes home to the business of man, and also to the highest elements of his moral nature. The nation that gathers together thousands of corals, shells, insects, fishes, birds, and beasts, and votes the requisite funds for preparing, preserving, housing and arranging them, derives the smallest possible return for the outlay by merely gazing and wondering at the manifold variety and strangeness of such specimens of Natural History.

The simplest coral and the meanest insect may have something in its history worth knowing, and in some way profitable. Every organism is a character in which Divine wisdom is written, and which ought to be expounded. Our present system of opening the book of Nature to the masses, as in the Galleries of the British Museum, without any provision for expounding her language, is akin to that which keeps the book of God sealed to the multitude in a dead tongue.

Finally, in reference to a National Museum of Natural History, I would respectfully solicit the attention of the Administrator to the successful working and unprecedented progress of the National Botanical Establishment at Kew, of the Museum of Practical Geology in Jermyn Street, and of the Museum of Practical Art at South Kensington, in reference to the relations of the eminent Directors of those establishments to Government. For this opens the question, whether in the event of acquiring, in whatever locality, the element essential to a National Museum of Natural History—space—any intermediate organization, unknown in the public establishments above cited, be really needed in the case of Natural History, in order to afford Parliament and the public the requisite guarantee of the good condition of the Collections, and the efficient discharge of the duties and functions of the National Museum of Natural History.

The sciences promoted by the statistical Section F., although bearing more immediately than any others on the prosperity of nations and the well-being of mankind, had no existence in the time of Bacon.

We look in vain for any evidence, for example, of a clear conception of Sanitary Science, or the doctrines preventive of disease, in the writings of that great philosopher and politician. The only approach to Statistics which we find in the 'Historia Vitæ et Mortis,' for example, is a collection of instances of longevity; and the main aim of that Essay seems to have been the extreme prolongation of particular or individual life, not the insurance of average longevity to the species. Some remarks on the advantage of pure air are congenial with the aims of the modern sanitary philosopher; but he finds no evidence of Bacon's conception of its importance to the masses, or of the means of ensuring it to populous cities, for prevention of plague and pestilence. Sanitary science, as a great power for mankind, in the Baconian sense, is of very recent growth: and, whether we consider the present evidence of its potency where it has been rightly applied, or the present evidence of the miserable results of its neglect, we must be stimulated to use every effort to promote its progress and impress its importance on all who may aid therein.

Long after Lord Bacon's day, the plague, the fever of the 'black assize,' and the like visitations, which drove Courts and Parliaments and Royal Societies from town to country, were met only by rude quarantine imprisonments of the sick, which greatly aggravated the sum of mortality. Accidents, such as the fire of London, subliming much old and vested filth, and followed by wider streets and better dwellings, produced results which opened the eyes of a few thinkers to the relation between certain physical conditions and the non-return of the plague.

Now, however, these relations have been comprehensively investigated; the diseases produced or aggravated by preventible conditions are well known; the most efficient and economical modes of prevention have been the subject of successful and convincing experiment. But men are slow to act where the profitable result is not direct. Health, we call, with cuckoo-cry, the greatest blessing; but practically it is daily sacrificed to ambition, wealth, pleasure, and a hundred aims in which duty takes no necessary part. That, however, is an affair of individual free-will with which abstract science has no business.

But in reference to inevitable aggregates of mankind, the nation is concerned in the science which seeks their especial bodily well-being. Fleets, armies, manufactories, workshops, the localities in towns where wage-people* congregate,—such are conditions of citizens in which it behoves the State, to the utmost constitutional extent of its power, to apply the ascertained means of preventing disease and death.

Perhaps the most exemplary instances of the value and economy of sanitary science are afforded by the records of the British Navy, especially since the period of Capt. Cook, whose name, were I to select one, as a prime promoter of the science, would be that which I should adduce with highest veneration. Some of the Arctic Expeditions, also, illustrate in an exemplary degree the value of preventive measures in maintaining health under difficult and depressing circumstances.

Our armies have yet to receive the benefit of what is now known in the prevention of death by disease. To what extent they have to benefit by it has been made plain by the results of recent investigations, in which the testimony of Florence Nightingale shines forth as the beacon which lights to better measures.

* I venture to propose this term as free from the objections that have been made to "lower orders," "humbler classes," "poorer classes," "working classes," "labouring population," &c. The two former are a reflection on those who are so designated; and the two latter are an implied reflection on all other classes, as if left to a life of vacant inoccupation. They are injuriously misleading terms. The true specific character of the great class in question is seen by the Naturalist to be "payment by wages"; it is the "wage-class."

The results of the labours of the Sanitary Commissioners in the Crimea, although the application of their preventive science was an after-thought, and late, must have convinced the most sceptical of military men of its importance. It became one of the elements of the ultimately superior condition of the English part of the Allied army*.

How large a proportion of loss in the French force was due to the absence of neglect of preventive measures, we learn from the recent 'Relation Medico-chirurgicale de la Campagne d'Orient' of M. Scrive, the head of the Medical Department of the French army during that campaign; and from the admirable paper on the same subject by Dr. Gavin Milroy, Member of the Sanitary Commission to the British Army in the East. To cite our neighbour's case, in which the organization of the land-service has a high repute, out of a force which averaged during a period of twenty months 104,000, upwards of 193,000 men were sent into hospital, *i.e.* at the rate of from 9000 to 10,000 per month. About one-fifth of these admissions were from wounds and mechanical injuries; the rest were from disease. The deaths in the hospitals at Constantinople amounted to 28,000; elsewhere, as in the camp and the field-ambulances, the deaths were 28,400, exclusive of 7500 slain in action. Of the 28,400 deaths under treatment, about 4000, or a seventh part of the whole, arose from gun-shot wounds and accidents, the other six-sevenths being the result of disease. The official returns give a total loss from all causes during the whole Crimean campaign of 70,000: it is believed to have exceeded that figure by 10,000. 65,000 men, out of 309,268, sent from France and Algeria, were invalided in consequence of disablement from wounds or the effect of disease.

Dr. Scrive points out that, if the buildings at Gallipoli had been inspected

* These results cannot be better stated than in the words of Miss Nightingale, in an appeal for the organization of a preventive administration, founded on the sanitary history of the Crimean campaign.

"It is," she says, "a complete example—history does not afford its equal—of an army, after a great disaster arising from neglect, having been brought into the highest state of health and efficiency. It is the whole experiment on a colossal scale. In all other examples, the last step has been wanting to complete the solution of the problem. We had, in the *first* seven months of the Crimean campaign, a mortality among the troops of 60 per cent. per annum, from disease alone,—a rate of mortality which exceeds that of the great plague of London, and a higher ratio than the mortality of the cholera to the attacks; that is to say, there died out of the army in the Crimea an annual rate greater than ordinarily die in time of pestilence out of the sick. We had, during the *last six* months of the war, a mortality among our *sick* not much more than among our *healthy* Guards at home; and a mortality among our troops, in the last five months, two-thirds only of what it is among our troops at home. The mortality among the troops of the line at home, when corrected, as it ought to be, according to the proportion of different ages in the service, has been, on an average of ten years, 18·7 per 1000 per annum, and among the Guards, 20·4 per 1000 per annum. Comparing this with the Crimean mortality, for the last six months of our occupation, we find that the deaths to admissions were 24 per 1000 per annum; and during the last five months, viz. January to May 1856, the mortality among the troops did not exceed 11·5 per 1000 per annum. Is not this the most complete experiment in army hygiene?"

and made fit for the purpose before they were occupied as an hospital, a regiment of active young soldiers might have been saved.

At Varna, a Turkish barrack within the walls was prematurely occupied as an hospital: it had to be abandoned after great loss of life. Fewer men fell in the unsuccessful attack upon the Malakoff on the 18th of June than succumbed in the rash attempt to use, as an hospital, a place which had not been previously fitted for one. And the time and labour required by the Sanitary Inspector to effect their fitness are as nothing compared with the preliminary approaches to the Malakoff, and with the delay and impediments caused by the prostration of a large proportion of effective force by disease.

Without consulting the medical staff, it was determined to move from Varna to the notoriously malarial region on the south of the Danube, called the Dobrudscha. On the 20th of July the first division of the army moved from Varna; on the 26th the cholera broke out. Hundreds of men were struck down at once, and died within a few hours after being seized: in one regiment 300 men were attacked within twenty-four hours, and most of them died on the spot. Appalled by the blow, the commanding officer retreated, as from before an overwhelming force; but, ere he could reach the healthier locality, one-third of the division had perished, and numbers reached the coast only to expire on the beach.

No enemy had been encountered save that one, of whose power and presence sanitary science had in vain forewarned the commander. On the return of the first division to Varna, a force of 12,000 had been reduced to 7000; the victims including two general officers and seven medical officers.

Not to weary by other special instances of the effect of neglecting preventive preparatory sanitary measures, I may sum up by the statement that one pestilence, in the marshes of the Danube, within two months, out of an army 55,000 strong, and before a shot had been fired, had destroyed as many men as were slain by the enemy in the field during the twelve months from the landing in the Crimea to the capture of Sebastopol, and when the army averaged double the above number of men.

That this pestilence, or its fatal effects, might have been, in an important degree, prevented by practicable applications of sanitary science is the conviction of the ablest medical officers of the French and English armies; and this conviction was substantiated by the results of the Sanitary Commission which operated in the English lines before Sebastopol. These authorities concur in the conclusion that three-fourths of the losses of an army in the field are not from the enemy or from unavoidable casualties of service, "but from diseases which are more or less under control." "Of these," writes Dr. Milroy, "typhus and scurvy are two of the most formidable, and the most easily preventible. They are the inevitable products of certain well-ascertained conditions, and they may be generated at will as surely as any salt or other compound may be formed by the chemist in his laboratory.

And yet it was these very evils which but two years ago brought the noble army of a mighty nation, at the close, too, of a glorious campaign, to almost the verge of destruction."

I may allude to one other point which sanitary science would suggest to the administrator in reference to the clearly-ascertained effects of too little pure air, and too much foul air inspired continuously during a given period.

The skilled soldier being of a given value when landed healthy and strong in the Crimea or at Calcutta, query, whether it be more economical to carry 1000 in one ship, landing 500 sick, enfeebled, and prepared to fall into and engender epidemics, or to carry the 1000 in two such ships, and land them healthy and fit for action? The same administrative question applies to barracks and hospitals.

One noble use and adequate application of so vast a triumph of naval architecture as Mr. Scott Russell's 'Leviathan' would be its carrying troops in good condition as regards health, for which its capacity especially fits it.

When authority becomes impressed with a conviction stimulating to action of the importance of sanitary science, it will insist on the possession, by the army medical officers, of the elements of that science as well as of the principles of practice in the cases of disease and the treatment of wounds. But, in order that an army may benefit by the doctors' knowledge of preventive medicine, authority should direct preliminary examinations and reports of sites for encampment,—of buildings for barracks and hospitals,—of clothes for extreme climates, and the like, and should command that such reports be acted upon, where no urgent circumstances or inevitable movements preclude the adoption of the means for the prevention of decimating fevers and choleras.

Bonaparte's military science was characterized by the rapid concentration of his forces upon a given point. A like success and superiority may attend the commander who keeps the greatest proportion of his men in good working trim. The healthier the man the longer and quicker will he march. And the care which foresees and provides for the efficient fighting order of a force is quite compatible with the most intrepid handling of that force in the field of battle.

As to the dense populations in civil life, the number of towns in England in which the sewage is rapidly, efficiently, and economically carried off by water-power and hydraulic apparatus, constitute so many experimental demonstrations of the success attending a proper unintermitting water-supply and co-adjusted system of tubular drainage. Lancaster, Penrith, Alnwick, Barnard Castle, Rugby, Croydon, Ely, are instances in which are demonstrated the diminution of fever and other causes of untimely death,—the augmentation of the cleanliness and comfort of the wage-classes,—the economy in the wear of all washable articles through the supplies of pure water, —collateral and unexpected economies in regard to fire-insurance, from the power of rapid extinction of conflagration which the unintermitting system affords,—the purity of the atmosphere in formerly fœtid courts and alleys,—these and other inestimable material advantages have resulted, and will result with progressively increased benefit as time goes on.

Lord Bacon observes, in his suggestions for an inquiry into the causes of death,—"And this inquiry, we hope, might redound to a general good, if physicians would but exert themselves and raise their minds above the sordid considerations of cure; not deriving their honour from the necessities of mankind, but becoming ministers to the Divine power and goodness both in prolonging and restoring the life of man; especially as this may be effected by safe, commodious, and not illiberal means, though hitherto unattempted. And certainly it would be an earnest of Divine favour, if, whilst we are journeying to the land of promise, our garments, these frail bodies of ours, were not greatly to wear out in the wilderness of this world."

Amongst his special topics of inquiry are these:—

"Inquire into the length and shortness of men's lives according to the times, countries, climates, and *places* in which they were born and lived."

"Inquire into the length and shortness of men's lives according to their food, diet, manner of living, exercise, and the like. With regard to the *air* in which they live and dwell, I consider that ought to be inquired into under the former article concerning *their places of abode*."

Now these inquiries have in our times been made chiefly in the form and by the authority of Sanitary Commissions; in the successful working of which the name of Edwin Chadwick stands foremost.

By these commissions it has been shown, as a general result, that nearly one-half the prevalent diseases are due to one or other form of atmospheric impurity; impurity from decomposing fæcal or animal and vegetable matter, within and without human habitations, and beneath the sites of towns, and atmospheric impurity from over-crowding.

For the prevention of the diseases arising from these causes, the sanitary physician must direct his requisitions not to the apothecary, but to the professor of new arts, which are only partially created,—the art of the sanitary architect and the art of the sanitary engineer. The latter has already been officially shown how he may collect water from natural and artificial springs, convey it into houses unintermittingly fresh, and without stagnation, and by its means remove from houses, through self-cleansing drains and self-cleansing sewers, constantly and before noxious decomposition can commence, all fæcal and waste animal and vegetable matter.

In model dwellings, where the sanitary conditions have been as yet applied only in a rudimentary manner, the death-rate has, in fact, been steadily kept down to thirteen in a thousand, or much less than one-half that which prevailed in London when Bacon lived, or little more than one-half of the death-rate which prevails there now. In fact, it is proved to be practicable to make those garments—the frail bodies of the population—last full ten years, or probably one-third longer, in the wilderness of this world.

In our time physicians have ably exerted themselves in aid of the sanitary engineer and administrator. Their general sentiments have been long expressed in such terms as those of Dr. Willis of Kelso:—"It is impossible to avoid the conclusion that much more might still be accomplished could we be induced to profit by a gradually extending knowledge, so as to found upon it a more wisely directed practice. When man shall be brought to acknowledge (as truth must finally constrain him to acknowledge) that it is by his own hand, through his neglect of a few obvious rules, that the seeds of disease are most lavishly sown within his frame, and diffused over communities; when he shall have required of medical science to occupy itself rather with the prevention of maladies than with their cure; when governments shall be induced to consider the preservation of a nation's health an object as important as the promotion of its commerce or the maintenance of its conquests, we may hope then to see the approach of those times when, after a life spent almost without sickness, we shall close the term of an unharassed existence by a peaceful euthanasia."

It is to the landlord,—to the representative landlords and owners of habitations,—in parliament, to whom exhortations are now required to be addressed, to raise their minds above "the sordid considerations" of the expenses of cure, that is, of the expenses of those sanitary works of combined drainage and water-supply, which it is their province to provide.

It is right, however, to state that advances in well-directed practical applications of sanitary science are advances in economy; that two houses and two towns may receive constant supplies of water at the expense formerly incurred for supplying one on the intermittent system, with its stagnancy and pollutions in house cisterns and large storage reservoirs. It remains for the legislature and local administrations to make prevalent that which is proved to be practicable for the public good, and to ensure that good at the economical rate at which particular instances afford demonstrations that it is achievable.

Agriculture has of late years made unusual progress in this country, and much of that progress is due to the application of scientific principles; chiefly of those supplied by chemistry, in a less degree of zoology and physiology: some minor help in regard to the more effectual abatement of noxious insects has been had from entomology; recent discoveries of the metamorphoses, metagenesis, and the course and modes of transmission of internal parasites, have afforded a rational explanation of some traditional precautionary rules of herdsmen, in reference to the 'rot' in sheep, from fluke-worms and hydatids; and more direct power of preventing epizootics will doubtless be obtained from entozoology.

Geology now teaches the precise nature and relations of soils, a knowledge of great practical importance in guiding the drainer of land in the modifications of his general rules of practice. Palæontology has brought to light unexpected sources of valuable manures, in phosphatic relics of ancient animal life, accumulated in astounding masses in certain localities of England, as, for instance, in the red-crag of Suffolk, and the greensands of Cambridge.

But enormous quantities of azotic, ammoniacal, and phosphatic matters are still suffered to run to waste; and, as if to bring the wastefulness more home to conviction, these products, so valuable when rightly administered, become a source of annoyance, unremunerative outlay, and disease, when, as at present in most towns, imperfectly and irrationally disposed of.

For the most part, thought is taken only how to get rid of these products in the easiest and quickest way. The metropolitan authorities have hitherto carried the chain of reasoning no further. They have turned them into the Thames, the receptacle nearest at hand; but in so doing have failed in their prime intention. The metropolis is not even rid of its excreta; but they have returned upon it and accumulated, with increased noxious and morbific power, on the strands of the valley that bisects it; appealing, as is notorious, summer after summer, to the very legislature itself, with unintermitting and importunate odours, compelling the attention of the possessors of lands and houses to this important subject.

Now here I would beg leave to remark that, in the operations of Nature, there is generally a succession of processes coordinated for a given result: a peach is not directly developed as such from its elements; the seed would, *a priori*, give no idea of the tree, nor the tree of the flower, nor the fertilized germ of that flower of the pulpy fruit in which the seed is buried. It is eminently characteristic of the Creative Wisdom, this far-seeing and prevision of an ultimate result, through the successive operations of a coordinate series of seemingly very different conditions.

The further a man discerns, in a series of conditions, their cordination to produce a given result, the nearer does his wisdom approach—though the distance be still immeasurable—to the Divine wisdom.

One philanthropist builds a fever-hospital, another drains a town. One crime-preventer hangs the man, another trains the boy. One financier would raise money by augmenting a duty, or by a direct tax, and finds the revenue not increased in the expected ratio. Another diminishes a tax, or abolishes a duty, and through foreseen consequences the revenue is improved.

Quarantine exemplifies only the first step in the progress of thought, bearing on the prevention of a dreaded distemper. It is a system which might keep out contraband goods or uncertified strangers, but it is powerless against the gaseous factors of plague, cholera, or yellow fever. No European country suffers more from such maladies than Naples or Portugal, where quarantine regulations are most stringent.

Agriculture, let me repeat, has made and is making great and encouraging progress. But much yet remains to be done. Were agriculture adequately advanced, the great problem of the London sewage would be speedily solved.

Can it be supposed, if the rural districts about the metropolis were in a condition to avail themselves of a daily supply of pipe-water not more than equivalent to that which a heavy shower of rain throws down on 2000 acres of land, but a supply charged with 30 tons of nitrogenous ammoniacal principles, that such supply would not be forthcoming, and made capable of being distributed when called for within a radius of 100 miles? I believe that, were the call made as loudly as it undoubtedly would be under the exigencies of a more advanced stage of agricultural mechanics, the skill of our engineers, with the constructive powers of our machine-makers, both carried to a degree of perfection which the world never before saw, would speedily and successfully meet the call, and leave nothing but the rainfall of the metropolis to seek its natural receptacle—the Thames.

To send ships for foreign ammoniacal or phosphatic excreta to the coast of Peru, and to pollute by the waste of similar home products the noble river bisecting the metropolis, and washing the very walls of our Houses of Parliament, are flagrant signs of the desert and uncultivated state of a field where science and practice have still to cooperate for the public benefit.

To promote this cooperation, effectual aid may be given by a recently established kindred Association, through the advancement of the legislative and administrative sciences. For it is the present condition of those social sciences which forms the chief obstacle to the practical application of Sanitary science. Of this science, it may be confidently averred that, besides providing means for the relief of town-populations from excessive sickness, it has, in a sufficient number of instances, provided means for the prevention of the pollution of rivers as well as for applying the manure of towns to fertilize the land.

The application of those means now rests with the Legislator and Administrator, and involves questions which are not within the province of the British Association*.

Some of our sciences are deeply concerned in one progressive step,—the uniformity of standard in measure and weight throughout the civilized world; in urging on which step, energetic and unwearied efforts are now being made by a Committee of our fellow-labourers of the Royal Society of Arts, amongst whom the name of the prime promoter of this and kindred reforms, Mr. James Yates, deserves especial and honourable mention.

Chemistry is more concerned in the uniform expression of the results of her delicate balances amongst her cultivators of different countries: Natural History is no less interested in the use, by all observers, of one and the same scale for measuring, and of one set of terms for expressing the superficial dimensions of her subjects. Practically, I may state that I have found the

* Services on three successive Sanitary Commissions, on the First Consolidated Metropolitan Sewers Commission, and at the Board of Health, have led me to enter at undue length on Sanitary matters, and are pleaded in excuse.

French mètre, and its subdivisions down to the millimètre, adequate to give all the needful data of this kind for comparison of superficial dimensions in the varied and extensive range of objects to which my business and pursuits have led me to pay attention. Of the hindrances to progress and inconveniences of the 'foot,' the 'inch,' and its duodecimal parts or lines,—rarely the same in any two countries,—I have elsewhere spoken and argued.

The whole subject of a uniform system of weights, measures, and current coin, will occupy the attention of a section of the Association for the Advancement of Social Science, which will meet at Liverpool shortly after the termination of the present Meeting. This is by no means the only point at which the Natural and Social Sciences touch and react on each other with mutual advantage. The proximity of the periods of the annual assemblage of the promoters of these respective sciences, together with the occurrence of both, this year, in the North of England, is favourable to the fruition of such advantages, by facilitating attendance at both Associations: and in future years, the conditions of time and place of meeting, making it easy for a Member of the British Association to attend also the Association for Social Science, and reciprocally, might, with a view to mutual advantage and cooperation, be a subject worthy of the consideration of the respective Councils of those Bodies.

In reference to the relations now subsisting between the State and Science, my first duty is to express our grateful sense of such measure of aid, cooperation, and countenance as has been allotted to Scientific Bodies, Enterprises and Discoveries; more especially to acknowledge how highly we prize the sentiments of the Sovereign towards our works and aims, manifested by spontaneous tribute to successful scientific research, in honourable Titles and Royal gifts, and above all, in the gracious expressions accompanying them, with which Her Majesty has been pleased to distinguish some of our Body. Happy are we, under the present benignant Reign, to have, in the Royal Consort, a Prince endowed with exemplary virtues, and with such accomplishments in Science and Art as have enabled His Royal Highness effectually, and on some memorable occasions, in the most important degree, to promote the best interests of both. We rejoice, moreover, in the prospect of being favoured at a future Meeting by the Presidency of the Prince Consort; and that, ere long, this Association may give the opportunity for the delivery of another of those 'Addresses,' pregnant with deep thought, good sense, and right feeling, which have placed the name of Prince Albert high in the esteem of the Intellectual Classes, and have engraven it deeply in the hearts of the humblest of Her Majesty's subjects.

On the part of the State, sums continue to be voted in aid of the means independently possessed by the British Museum and the Royal Society, whereby the Natural History Collections in the first are extended, and the more direct scientific aims of the latter Institution are advanced. The

Botanical Gardens and Museum at Kew, and the Museum of Practical Geology in Jermyn Street, are examples of the National Policy in regard to Science, of which we can hardly over-estimate the importance. Most highly and gratefully also do we appreciate the cooperation of the 'Board of Trade' with our Meteorologists, by the recent formation of the Department for the collection of meteorological observations made at sea.

But not by words only would, or does, Science make return to Governments fostering and aiding her endeavours for the public weal. Every practical application of her discoveries tends to the same end as that which the enlightened Statesman has in view.

The steam-engine in its manifold applications, the crime-decreasing gas-lamp, the lightning conductor, the electric telegraph, the law of storms and rules for the mariner's guidance in them, the power of rendering surgical operations painless, the measures for preserving public health and for preventing or mitigating epidemics,—such are amongst the more important practical results of pure scientific research with which mankind have been blessed and States enriched. They are evidence unmistakeable of the close affinity between the aims and tendencies of Science and those of true State policy. In proportion to the activity, productivity, and prosperity of a community is its power of responding to the calls of the Finance Minister. By a far-seeing one, the man of Science will be regarded with a favourable eye, not less for the unlooked-for streams of wealth that have already flowed, but for those that may in future arise, out of the applications of the abstract truths to the discovery of which he devotes himself.

This may, indeed, demand some measure of faith on the part of the practical Statesman. For who that watched the philosophic Black experimenting on the abstract nature of Caloric could have foreseen that his discovery of latent heat would be the stand-point of Watt's invention of a practically operative steam engine! How little could the observer of Oersted's subtle arrangements for converting electric into magnetic force have dreamt of Wheatstone's application of such discovery to the rapid interchange of ideas now daily practised between individuals in distant cities, countries, and continents!

Some medical contemporaries of John Hunter, when they saw him, as they thought, wasting as much time in studying the growth of a deer's horn as they would have bestowed upon the symptoms of their best patient, compassionated, it is said, the singularity of his pursuits. But, by the insight so gained into the rapid enlargement of arteries, Hunter learnt a property of those vessels which emboldened him to experiment on a man with aneurism, and so to introduce a new operation which has rescued from a lingering and painful death thousands of his fellow-creatures. Our great inductive physiologist, in his dissections and experiments on the lower animals, was "taking light what may be wrought upon the body of man."

The production of chloroform is amongst the more subtle experimental results of modern chemistry. The blessed effects of its proper exhibition in the diminution of the sum of human agony are indescribable. But that divine-like application was not present to the mind of the scientific chemist who discovered the anæsthetic product, any more than was the gas-lit town to the mind of PRIESTLEY or the condensing-engine to that of BLACK.

These unexpected applications of pure Science, fraught with such incalculable influences on the well-being of peoples, ought to weigh with the Minister to whom may be submitted an enterprise in Science which only a nation can undertake, or the considerations of a scientific establishment which none but a nation can support, Much of the improvement in refined machinery, and the tools for making it, grew out of the requirements and teaching of BABBAGE during the construction of his Calculating Machines. Such collateral result, alone, has made a manifold return for the sum granted in aid of the realization of that philosopher's great idea. So rare a combination of analytic, inventive, and constructive faculties is seldom given to man; and the generation witnessing such a mind in operation would be wise to secure the full result of its peculiarly directed energy.

In proportion to the facilities and rapidity of exchange and transit of goods, of men, and of thought, trade and commerce expand; and with their expansion grow the receipts under the heads of Customs and Excise. Every application of pure mathematics and astronomy to the making voyages safer and speedier,—every observation by such instruments as the Establishment of the British Association at Kew perfects for their purpose, giving to the mariner fore-knowledge of storms, and teaching him their course and lines of greatest intensity,—becomes an important condition in enabling a country to bear the burthen of taxation.

The steps in the series of this relation have been so plain that national encouragement has long been given to Astronomy. As clear a perception of the same relation and tendency of discoveries in Chemistry, Electricity, Electro-magnetism, and other sciences, led Herschel, long ago, to ask "Why the direct assistance afforded by Governments to the execution of continued series of observations should be confined to Astronomy?"

Faithfully is the State served by that Science. Most exemplary are those observations made, and every astronomical duty bearing on the interests of society, discharged, in the Royal Observatory at Greenwich, the good repute of which grows and spreads year by year under its present indefatigable Chief. Year by year, almost, arises the necessity for some additional instrument to meet the ever-expanding relations and requirements of Astronomy and Meteorology.

But to make use of fitting instruments is one thing, to make them fit for use another. To perfect that fitness and extend it to the instruments of all observatories, to maintain a standard of excellence whereby comparison of results shall be most productive of truth, are the special functions of our kindred establishment at Kew. There, as in the mathematical and engine houses of the 'New Atlantis,' we seek to render our instruments unrivalled "for equality, fineness, and subtilty" of operation. No expense, time, or pains have been spared by this Association to bring the exquisitely constructed and ingeniously adjusted mechanisms required to give us cognizance of the operations of the mysterious influences pervading our earth and atmosphere to their utmost attainable exactitude of performance.

To prepare, to adjust, to test, verify, and rectify those instruments for the use of voyagers and travellers are labours that have grown out of the important function of the 'Kew Observatory.'

These labours have been cheerfully performed whenever and by whomsoever required; as, recently, at the request of the Admiralty and Royal Society in aid of the Commission for determining the Oregon Boundary, and in the Second Expedition of Livingstone to the Zambesi. Not only have philosophical instruments been prepared and constants determined, but the voyagers have received, at Kew, practical instructions in their use.

The reputation of the accuracy of the instruments at our establishment is now such that requests are received from different Foreign States for a like application of the resources which it commands. The United States, Russia, Austria, Portugal, the Papal States for the 'Collegio Romano,'—all have testified, by such applications for the preparation and adjustment of philosophical instruments, that the establishment, originated and organized by the British Association, fulfils a national scientific want. Our 'Report' this year will show that the Admiralty, the Board of Trade, and other Home-institutions give the same testimony.

With the growth of its reputation and experience of its utility, the labours carried on at Kew have necessarily multiplied; and the expense of the establishment cannot be this year less than £800.

Were the duties of the Kew Observatory superadded to those performed at Greenwich, such expense would fall, in the ordinary course, upon the State. Hitherto it has been borne by the British Association, and to that extent cripples our power of lending the helping hand to other scientific work.

We have to thank the Government for the use of the building at Kew.

Such pecuniary aid as has been added to the sums allotted from our subscriptions has been received from a kindred self-supporting Scientific Association. The Royal Society liberally voted the amount required for the purchase of the "Whitworth's Lathe and Planing Machine," now doing efficient work at the Observatory.

In the late location, by liberal permission of the Government, of the Royal, Linnæan, and Chemical Societies in contiguous apartments at Burlington House, we hail the commencement of that organization, recommended by the British Association at their first meeting, from which the most important results of combination of present scattered powers, and of a system of intellectual cooperation, may be confidently expected. "The combined advantages, including at once the most powerful stimulus and the most efficient guidance of scientific research," have appeared to an eminent member of our Body "to be beyond calculation."

No locality in the Metropolis unites so many elements of convenience for such a concentration as Burlington House. If, to the application of other Scientific Societies than the three now there located, the reply should be given "that the State is not called upon to provide room for individuals who may choose to combine for the enjoyment of a special intellectual pursuit," we may rejoin that such Associations seek no selfish profit, but impart the results of their combined labour freely for the public weal. We might urge that the small amount of support needed for the enterprises and establishment of Science,—scarce equal to the product of the tax upon discovery and invention paid under the existing 'Patent Laws'—would be a good investment on the part of a Nation; and that, viewing such establishments and the prosecution of abstract physical truth in regard only to their material results, these might assure a Minister disposed to invest in what might seem to him the Lottery of Science, that the prizes are neither few nor small,—nay, some are incalculably great.

It now only remains for me to express how deeply I feel the honour conferred on me by the position in which, through your kindness, I am now placed; how highly I esteem the opportunity afforded me of addressing so distinguished and influential an audience in this most noble Hall; and how sincerely I thank you for the patience and favour with which you have received this Address.