think of this great event? The volcano has come to an eruption; everything is in flames, and we have no longer a transaction with closed doors!' 'Terrible affairs,' said I, 'but what could be expected under such outrageous circumstances, and with such a ministry, otherwise than that the whole would end with the expulsion of the royal family?' 'My good friend,' gravely returned Goethe, 'we seem not to understand each other. I am not speaking of those creatures there, but of something quite different. I am speaking of the contest, so important for science, between Cuvier and Geoffroy Saint-Hilaire, which has just come to an open rupture in the French Academy!'" This individual contest between two giants was the signal for a general outbreak. The first gun was fired and a war ensued, which has continued with almost unabated vigor until the present time. The scientific world was divided into two camps, those who sympathized with the views of Geoffroy regarding Evolution, and those who sided with Cuvier, the advocate of the traditional doctrine of special creations.

Much, however, remained to be accomplished before the views of Saint-Hilaire could be considered as anything more than a provisional hypothesis. The evidence of all the sciences had to be weighed, a thorough survey of the vast field of animate nature had to be made, before the new school could reasonably expect its views to meet with general acceptance. Special and systematic investigations were accordingly inaugurated, in all parts of the world, in which representatives of every department of science took an active and interested part.

CHAPTER IV.

SPONTANEOUS GENERATION AND SCIENTIFIC DISCOVERY.

Early Views Regarding Abiogenesis.

BEFORE recounting the results of these investigations, it may not, perhaps, be out of place, briefly to summarize a chapter in the history of biology which has always had a peculiar interest for students of nature, and which, even to-day, notwithstanding many long and animated controversies on the subject, has probably a greater interest for a certain school of evolutionists than almost any other one topic. I refer to the subject of spontaneous generation, or abiogenesis,[1] to which reference has already been made *en passant*.

The discussion of this question has played such an important part in the history of science, that any treatment of the theory of Evolution which should contain no reference to the subject of spontaneous generation, would ignore one of the most essential factors in a great and long-continued controversy. In good sooth, some knowledge of the more salient facts of abiogenesis are absolutely indispensable to a proper appreciation of certain of the most interesting problems connected with the theory of Evolution

[1] Generatio æquivoca, heterogenesis, and autogenesis, are sometimes employed as synonyms of spontaneous generation.

as now understood. In many respects, indeed, Evolution and abiogenesis go hand in hand and what throws light on the one at the same time illuminates the other, diminishing, *pari passu*, the difficulties of both, or bringing, it may be, such difficulties into bolder relief.

The doctrine that certain animals and plants arise from the fortuitous concourse of atoms of inorganic matter, or originate from decaying animal or vegetable matter, that nature is capable of bringing forth living bodies,

"Qui rupto robore nati,
Compositive luto, nullos habuere parentes."

is one of those errors in science that can be traced back to the earliest period of scientific speculation. It received the *imprimatur* of Aristotle, who was a firm believer in spontaneous generation, and, like many other errors indorsed by the famous Stagirite, it was almost universally accepted as incontestable truth until a few decades ago. How much this belief, by engendering false notions regarding the unity and relationship of the animal world, may have retarded the progress of science, it is unnecessary here to inquire. Suffice it to say that the discussions to which the subject gave rise from time to time had no slight influence in predisposing many minds in favor of the theory of Evolution, and of throwing a certain light on the subject of organic development that could come from no other source.

According to Aristotle many of the lower forms of animal life originate spontaneously, sometimes

from decomposing animal or vegetable matter, sometimes from the slime of the earth. Many insects, he tells us, spring from putrid matter; certain fish have their origin in mud and sand, while eels, we are assured, are spontaneously produced in marshy ponds.[1] Aristotle's views were shared by his countrymen as well as by the Romans—by poets and philosophers as well as by naturalists. Pliny and Varro speak of spontaneous generation as do also Virgil and Lucretius and Ovid. All readers of Ovid are familiar with the interesting account given in the "Metamorphoses" of the origin of bees, hornets and scorpions from putrid flesh, of frogs from slime, and of serpents from human marrow.[2]

Entertaining such notions regarding the origin of living things, we can understand why Rome's poet-philosopher declares "It remains, therefore, to believe that the earth must justly have obtained the name of mother, since from the earth all living

[1] See his "History of Animals," book V, chap. I, and book VI, chaps. XIV and XV.

[2] "Si qua fides rebus tamen est addenda probatis,
Nonne vides, quæcumque mora fluidove calore
Corpora tabuerint, in parva animalia verti?
I quoque, delectos mactatos obrue tauros;
Cognita res usu, de putri viscere passim
Florrilegæ nascuntur apes . . .
Pressus humo bellator equus crabronis origo est.
Concava littoreo si demas brachia cancro;
Cetera supponas terrae; de parte sepulta
Scorpius exibit . . .
* * * * * * * * *
Semina limus habet viridea generantia ranas.
* * * * * * * * *
Sunt qui, cum clauso putrefacta est spina sepulchro,
Mutari credant humanas angue medullas."
Ovid, "Metamorphoses," Lib. XV., vv. 361, et seq.

creatures were born. And even now many animals spring forth from the earth, which are generated by means of moisture and the quickening heat of the sun." [1]

Fathers and Schoolmen on Abiogenesis.

The views of Aristotle and his successors were accepted and taught by the Fathers and the Schoolmen of the Middle Ages. St. Augustine, in discussing the question whether certain small animals were created on the fifth or sixth day, or whether they arose from putrid matter, says: "Many small animals originate from unhealthy vapors, from evaporations from the earth, or from corpses; some also from decayed woods, herbs and fruits. But God is the creator of all things. It may, therefore, be said that those animals which sprang from the bodies, and especially the corpses, of other living beings, were only created with them *potentialiter* and *materialiter*. But of those which spring from the earth, or water, we may unhesitatingly say that they were created on the fifth and sixth days." St. Thomas Aquinas acquiesces in this opinion of the great bishop of Hippo, although he declined to accept Avicenna's theory that all animals could originate spontaneously.

I direct special attention to the teachings of the Fathers and Schoolmen regarding abiogenesis, as

[1] "Linquitur, ut merito maternum nomen adepta
Terra sit, e terra quoniam sunt cuncta creata,
Multaque nunc etiam existant animalia terris
Imbribus, et calido solis concreta vapore."
Lucretius, "De Rerum Natura," Lib. V. 793–796.

they have a profound significance in the discussion of certain questions which shall be referred to in the sequel. The principles which they admitted have an importance that is far-reaching, and should be more generally known than they are. For the application of these principles—broad and deep they are—will enable us to refute many objections that would otherwise be unanswerable, and enable us to escape from many difficulties which frequently give both scientists and theologians no inconsiderable trouble.

For centuries after the time of St. Thomas, the theory of spontaneous generation was universally held and taught in all the schools of Europe.

And more than this. Learned men of science and grave theologians did not hesitate to give instructions as to how certain animals might be brought into existence by the mysterious power of abiogenesis. As late as the seventeenth century, the famous Jesuit scholar, Athanasius Kircher, confidently indicated the following method of producing serpents by spontaneous generation: "Take as many serpents as you like, dry them, cut them into small pieces, bury these in damp earth, water them freely with rain water, and leave the rest to the spring sun. After eight days the whole will turn into little worms, which, fed with milk and earth, will at length become perfect serpents, and by procreation will multiply *ad infinitum*." Van Helmont gave a recipe for making fleas, while there were others who gave equally explicit directions for the production of mice from cheese, or fish by the fermentation of suitable material.

Even so late as the last century, there were learned men who did not hesitate to declare that mussels and shell-fish are generated from mud and sand, and that eels are produced from dew.

Redi's Experiments.

The first one effectively to controvert the doctrine of abiogenesis was Francesco Redi, of the celebrated *Academia del Cimento*, of Florence. In his remarkable work entitled "Esperienze intorno alla Generazione degl' Insetti," published in 1668, he distinctly enunciates the doctrine that there is no life without antecedent life—*omne vivum ex vivo*—that all living organisms have sprung originally from preëxisting germs, and that the apparent production of organized beings from putrefied animal matter, or vegetable infusions, is due to the existence or introduction of germs into the matter from which such beings seem to originate.

The experiments by which Redi proved his assertion were as simple as they at the time were conclusive.

He placed some meat in a jar and then tied fine gauze over the top of the jar. The meat underwent putrefaction but no maggots appeared. Redi hence inferred that maggots are not generated by decomposing meat, but by something which is excluded from the jar by the gauze. He soon discovered that this something which had eluded all previous observers, was the eggs of a blow-fly, which, when deposited on meat, or dead animals, invariably gave rise to the maggots that had hitherto been

regarded as spontaneously generated. By a series of similar experiments he showed that in all cases the apparent production of living from dead matter was due to the introduction, from without, of living germs into the matter from which life seemed to originate.

So deeply rooted, however, was the doctrine of spontaneous generation in the minds of men, that Redi's conclusions were far from meeting with ready acceptance. All kinds of objections were urged against his experiments and the inferences which he drew from them. Some of his opponents even went so far as to assert that his conclusions were contrary to the teachings of Scripture, which, they contended, manifestly implied, if it did not expressly affirm, the doctrine of abiogenesis. In proof of their view they referred to the generation of bees from the lion which had been slain by Samson, and which suggested the riddle that so puzzled the Philistines:—"Out of the eater came forth meat, and out of the strong came forth sweetness." [1]

From our present way of viewing the question such an objection seems very strange, to say the least, but stranger still does it appear when we reflect that it was urged in the name of theology and Scripture. The spell of antiquity and authority was still hanging over the students of nature, and it re-

[1] Judges, chap. xiv, 5–14.—Redi refers to the objections of his adversaries in the following passage from his "Esperienze:" "Molti e molti altri ancora vi potrei annoverare, se non fossi chiamato a rispondere alle rampogne di alcuni che brusquamente mi rammentano ciō che si legge nel capitolo quattordicesimo del sacrosanto Libro de' Giudici." p. 45.

quired an intrepid investigator like Redi, strong in his sense of right and certain in his interpretations of the teachings of experiment, to assert his intellectual freedom, and to cope with those who imagined that Aristotle could not err, and that certain metaphysical dicta, which were universally quoted, were, in natural science, to be accounted as so many canons of truth.

But, notwithstanding the opposition which he excited, Redi was triumphant, and for a long time the theory of spontaneous generation was very generally looked upon as something that had fallen into disrepute.

Later Researches.

But the victory was but temporary. The invention of the microscope, and the discovery of the world of infusorial animalculæ, which before had been invisible, resurrected the old theory of abiogenesis, and many eminent naturalists now defended it as strenuously as had any one of its supporters before the experiments of Redi had called it in question.

Among the most eminent champions of the theory of the spontaneous generation of infusory animalcules, were the English naturalist, Needham, and the distinguished French savant, Buffon. As the result of numerous experiments both these observers came to the conclusion that, whatever views might be entertained regarding the origin of the higher forms of animal life, there could be no doubt about the spontaneous production of certain

of the lower animalculæ, from suitably prepared infusions of animal or vegetable matter.

This apparent victory was, however, but ephemeral. The experiments in question were taken up by a distinguished Italian ecclesiastic, the Abbate Spallanzani, who subjected them to a rigid and exhaustive examination. The result of his labors issued in proving incontestably that the experiments of Needham were defective, and that his conclusions, therefore, were unwarranted. Spallanzani demonstrated that when the necessary precautions are taken against the admission of germs into the infusions employed, no animalcules whatever are developed, and that the theories and conclusions of Buffon and Needham were not sustained by the facts in the case.

But, notwithstanding the investigations of Redi and his successors, Leeuwenhoek, Swammerdam, Reaumur and Vallisneri, and despite the researches of Spallanzani, Schultze and Schwann, Van Siebold, Leuckart, and Van Beneden, there were not wanting men who still pinned their faith to the theory of abiogenesis. Foremost among these were the celebrated chemists Berzelius and Liebig. "Was it certain," they asked, "that in the experiments which had hitherto been conducted, that the properties of the air, or oxygen of the air, or of the menstrua themselves, had not been essentially changed, and thus had rendered them incompetent to give rise to the phenomena which they would exhibit in their natural and chemically unchanged condition?"

These questions were taken up and answered in the epoch-making researches of that prince of investigators, the universally revered and world-renowned Pasteur. He demonstrated that in every instance life originates from antecedent life — *omne vivum ex vivo* — that the various forms of fermentation, putrefaction and disease are not only caused by the presence and action of certain microbes, but that these microbes, as well as organisms of a superior organization, are invariably produced by beings like themselves; that, in all cases, like proceeds from like, and that, consequently, spontaneous generation is, to use his own characterization of it, a "chimera."

Is the discussion finally closed? Has the theory of abiogenesis received its *coup de grâce?* At the present moment Pasteur and his school are undoubtedly lords of the ascendant. Will they always remain so? Time alone can answer this question. In the opinion of such men as Pouchet and Bastian, two of Pasteur's ablest antagonists, the question, so far as experiment goes, is at best settled only provisionally, and the same old controversy may break out any day, as it has so often broken out since the time of Redi, when it was declared to be definitively closed.

But, whatever be the last word of science respecting abiogenesis, the discussion of the subject has led to the discovery of many new facts of inestimable importance, and has vastly extended our view of the domain of animated nature. It has disclosed to our vision a world before unknown, the world

of microbian life — a world which has been aptly described as "the world of the infinitely little."

General Advance in Science.

The general progress of science, however, points towards some process of Evolution far more unmistakably than does anything disclosed during the long controversy regarding spontaneous generation.

Geology and physical geography have taught us that our earth is subject to mutations and fluctuations innumerable; paleontology has revealed a world whose existence was not only not suspected, a few generations ago, but a world whose existence would have been unhesitatingly denied as contrary to both science and Scripture, if anyone had been bold enough to proclaim its reality. Far from being only six thousand years old, as was so long imagined, our globe, as the abode of life, must now, as is shown by the study of the multifold extinct forms entombed in its crust, reckon its age by millions, if not by tens of millions of years.

By the naturalists of the last century the number of known species of plants and animals was estimated at a few thousands, or a few tens of thousands at most. But now, owing to the impetus which has been given to the study of zoölogy and botany, especially during the past few decades, the latest census of organic beings places the number of species at a million or more. Yet formidable as this number is, the list is far from being complete. Fresh additions are being made to it every day. The researches of naturalists in the many unexplored

fields of the earth; the investigations of microscopists in the boundless domain of microbian life; the dredging of the ocean depths in various parts of the globe by a constantly increasing corps of trained votaries of science, show that we are yet very far from having anything approaching a complete census of the rich and varied fauna and flora which adorn our planet.

But great as is the number of species actually existing, it is but a small fraction of those which are known to have lived and died since the dawn of life on the globe. A hundred million species or more, it has been computed, have appeared and died out since the time the *Eozoön Canadense* began its humble existence. And as our knowledge of the past history of the earth becomes more thorough, there is every reason to believe that we shall find this estimate, extravagant as it may appear to some, below, rather than above, the reality.

Synchronously with this advance in the knowledge of nature, the impression—which had all along been entertained by a greater or lesser number of philosophers and students of nature—has become stronger that all the changes and developments which the earth has witnessed; all the prodigality of form and size and color, which a bounteous nature has lavished upon a fauna and flora whose species are past numbering, is the result not of so many separate creative acts, but rather of a single creation and of a subsequent uniform process of Evolution, according to certain definite and immutable laws.

Chemistry and Astronomy.

The indications of paleontology and biology respecting Evolution have been corroborated by the revelations of chemistry, astronomy and stellar physics. Everything seems to point conclusively to a development from the simple to the complex, and to disclose "a change from the homogenous to the heterogenous through continuous differentiations and integrations."

It is simple elements that go toward building up organic and inorganic compounds. And while it is now generally believed that there are some three score and odd substances which are to be classed as elementary, there are, nevertheless, not wanting reasons for thinking that all the so-called elements are but so many modifications, so many allotropic forms, of one and the same primal kind of matter. The telescope discloses to us in the nebulæ which fleck the heavens, the primitive matter, the *Urstoff*, from which the sidereal universe was formed: "the gaseous raw material of future stars and solar systems." The spectroscope, in spite of Comte's dogmatic declaration, that we should never know anything about the chemical constitution of the stars, has not only given us positive knowledge regarding the composition of the heavenly bodies, but, thanks to the labors of Secchi, Huggins, Lockyer and others, has also furnished information concerning their relative ages, their directions of motion, and their velocities in space.

As the astronomer, the chemist, and the physicist view the material universe, it is constituted throughout

of the same material, a kind of cosmic dust, similar to, if not identical with, that which composes the existing nebulæ. No form of matter has yet been discovered in any of the heavenly bodies which is not found on the earth, and there is every reason to believe that in chemical constitution the visible universe is everywhere identical. And should it eventually be demonstrated that all the known chemical elements are only modifications of one primal form of matter, and this is far from impossible, or even improbable, then will be vindicated the old Greek theory of a primordial matter, πρῶτη ὕλη, a theory ardently championed by St. Gregory of Nyssa and his school, and defended in some form or other by many of the Schoolmen. And then, too, will the theory of Evolution be furnished with a stronger argument than any other single one that has yet been advanced in its support.

Testimony of Biology.

But great as was the influence of discoveries in geology, paleontology, microscopy, chemistry, astronomy and stellar physics, in preparing the minds of scientific men for the acceptance of the theory of organic Evolution, the arguments which had the greatest weight, which finally enlisted in favor of Evolution those who, like Lyell, still hesitated about giving in their adhesion to the doctrine of derivation, were those which were based on data furnished by the sciences of botany, zoölogy, physiology, and by those newer sciences, embryology and comparative osteology.

CHAPTER V.

FROM LORD BACON TO CHARLES DARWIN.

First Materials for the Controversy.

I HAVE spoken of the celebrated dispute between Cuvier and Geoffroy Saint-Hilaire, in which Goethe was so much interested. Materials for this controversy had been rapidly accumulating during the half century preceding the date when it finally broke out in the French Academy. Indeed, it would be truer to say that materials had been accumulating during two centuries prior to the historic debate between Cuvier and Geoffroy Saint-Hilaire. From the time of Bacon, Descartes and Leibnitz, more, far more, had been done towards the development of the Evolution idea than had been effected during all the centuries which had elapsed between the earliest speculations of the Ionian school and the publication of the "Novum Organum."

We have already learned what geology and paleontology contributed towards the establishment of the theory of Evolution. We have seen how the study of fossils and the careful and long-continued examination of the much-vexed question of spontaneous generation shed a flood of light on numerous problems which were before obscure and mysterious in the extreme. But while Da Vinci, Fracostoro, Palissy, Steno, Generelli, Redi, Malpighi, Leeuwenhoek, Schwammerdam and their compeers, were carrying on their