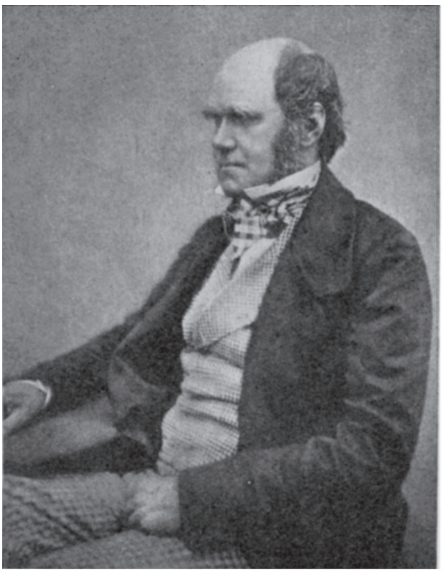
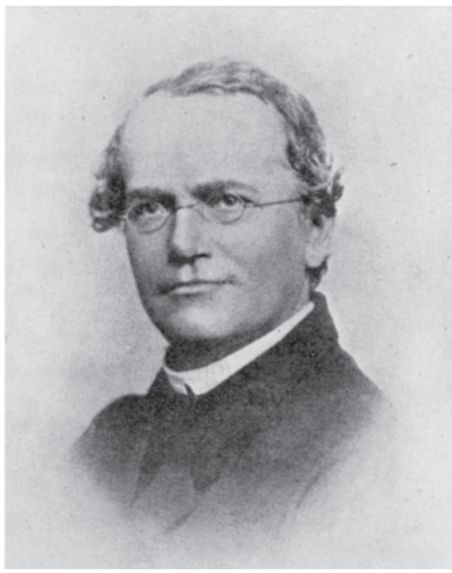
THE MECHANISM
OF
CREATIVE EVOLUTION



CHARLES DARWIN



GREGOR MENDEL

THE MECHANISM OF CREATIVE EVOLUTION

BY

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To the Memory of

CHARLES DARWIN
1809–1882

and

GREGOR MENDEL
1822–1884

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PREFACE

WE live in an age of scientific research when important discoveries are made every day and there is a danger lest, in the multiplicity of these discoveries, essential synthetic values may be lost in a maze of detail. After thirty years' experiments carried out in different parts of the world, with representative species of every type of living organism, the time seems to be ripe for a gathering together of the multitudinous facts which go to make up the genetical story of creative evolution. Future discoveries will no doubt enrich the story and fill in many details which are now missing, but the main mechanism of the genes and chromosomes which constitute the physical basis of creative evolution, has already been experimentally established, as shown in this book. Mendel's original discovery, developed by the experiments of Bateson and others and crowned by the brilliant work of Morgan and his colleagues, has led to consequences so far-reaching as to bring about one of the greatest revolutions that science has known, and has resulted in the elevation of biology to the rank of an exact science. The new science of genetics has confirmed and extended Darwin's law of natural selection and Mendel's laws of heredity, both experimentally and mathematically. One of these extensions is the genetical delimitation of species which has enabled us to place the study of creative evolution and its natural adjunct taxonomy, on the experimental basis of an exact science.

This century has also witnessed equally remarkable and revolutionary discoveries in the physical sciences and pure mathematics, which have given us entirely new views of the constitution of matter and of the universe around us. The discoveries of the chromosomes and genes and their inter-relations prove to be as important to the biologist as the discoveries of the atoms and electrons and their inter-relations are to the physicist. The gene is the unit of life and the genetical species is the unit of creative evolution. The far-reaching importance of these vital units to mankind can hardly be overestimated, since the genes are not only the basis of all structural and functional characters but, as recent work indicates, they are also the foundation of human thought and action.

It is evident that as a result of these discoveries, a critical period in human history has arrived. Man, if he chooses, can, here and now, take a hand in creative evolution by creating new species of living organisms and replacing natural selection by human selection. For a thousand million years natural selection, as one of the processes of creative evolution, has dominated life, and for ten million years it has dominated the human mind, obsessing Man with the idea of an overruling fate. Scientific research has brought freedom to Man, and the future trend of creative evolution, including Man's own destiny, depends entirely on his response to the new knowledge and on his intelligent application of these discoveries in the near and distant future.

My grateful thanks are due to genetical colleagues in various parts of the world, and to the publishers specified below, for their generosity in allowing me to reproduce illustrations. I am also much indebted to my wife who has helped me in my researches and has illustrated them in drawings which appear in this book.

C. C. H.

CAMBRIDGE
1932

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INTRODUCTION

EVOLUTION

IN its original meaning evolution represented a rolling out or unfolding, as in the development of an opening leaf or flower bud of a plant or the emergence of an animal from the egg. In this sense it was almost synonymous with the modern word ontogeny which signifies the somatic development of an individual organism from a spore, egg or embryo to its full development, decline and death. In other words, evolution was individual. In the eighteenth century, when the preformation theory of Bonnet was in the ascendant, evolution was used strictly in this sense and the idea persisted up to the time of Lamarck in the early nineteenth century. It is evident that the Lamarckian theory of the inheritance of acquired characters was based largely on the old ideas of individual evolution and variation. Eventually in Darwin's time evolution came to mean any changes, or "transformations" as they were called, in living organisms, whether individual or racial. Since the time of Darwin, the use of the word evolution has been extended far beyond its early meanings and has been applied in all directions. It is necessary therefore to point out that the evolution dealt with in this book is limited to organic evolution or more precisely the evolution of living organisms. The qualification "living" is necessary in view of Whitehead's recent application of the term "organism" to non-living matter. In this limited sense, evolution simply represents the origin of new kinds of living organisms from old ones.

CREATIVE EVOLUTION

The phrase "*L'Évolution Créatrice*" originated with the French philosopher Henri Bergson in his charming literary account of evolution. Naturally, as a philosopher, Bergson deals with the subject from the point of view of human values rather than from a biological standpoint. With the eye of a philosopher he perceives that evolution is, in the main, progressive. With the eye of a naturalist, the biologist observes that the evolution of living organisms as a whole represents a progressive system of increasing structural, functional and genic complexity, from the minute sub-cellular *Bacterium*, with its pre-cellular responses, to the multi-cellular mammal and primate *Homo*, with his reflective and conceptual mind. While neither accepting nor rejecting Bergson's vitalistic and orthogenetic theory of "*L'Élan vital*" but regarding it as redundant, many biologists have recognised that Bergson's description of evolution as "creative" is a true and apt expression of the biological facts. Before definitely adopting Bergson's literary and philosophical phrase as a scientific term, however, it is necessary that it should be more precisely defined in a scientific sense. For genetical biology a verbal definition is inadequate and it is necessary that there should be a quantitative and qualitative measure of creative evolution which can at any time be submitted to the test of genetical experiment. Recent work shows that in the genetical species we have such a unit which, though not entirely free from objection, is probably the most useful one available in the present state of knowledge. Since the time of Darwin the "good" taxonomic species has been used as a rough and crude measure of evolution, but experience teaches that this is a concept too vague and subjective to be used as a measuring rod of precision in a scientific age.

The genetical species proves in general to be a considerably larger unit than the ordinary Linnean species, being in many cases equivalent to a generic section or a sub-genus. It is measurable in terms of chromosomes and genes and consequently can at any time be precisely determined and tested experimentally. In this respect it provides a convenient and satisfactory biological unit of creative evolution which may be simply defined as the origin of new genetical species from old ones.

MECHANISM

The word "mechanism" in the title of this book has been used with some hesitation and doubt, since the word is always open to misconstruction when applied to living organisms. It is, however, a useful word to express the fact of the regular and orderly sequence of processes found in all healthy living organisms. So long as it is clearly understood that no ulterior materialistic meaning is attached to the word, no difficulty should arise. Evolution is not a deterministic machine, and creative evolution, as we shall see, is far from being mechanistic—on the contrary it is peculiarly indeterminate throughout all its phases. At the same time the chromosomes which play a great part in creative evolution have a definite visible mechanism of their own in the different stages of mitosis and meiosis which cannot be mistaken, and experiments show that the genes associated with them are equally concerned in this mechanism. The genetical mechanism is of course a living one or at least it is concerned with living entities, but it is none the less a mechanism expressing the regularity and orderliness of the activities and processes involved, in the same way that we speak of physiological, psychological and other biological mechanisms.

HISTORICAL

The idea of organic evolution is more ancient than is generally supposed, but in the nineteenth century of our era, the genius of Charles Darwin raised it to a high peak in popular thought. The speculations of the early Greek philosophers display a prophetic insight of modern ideas of evolution.

In the sixth century B.C., Anaximander conceived the idea of a gradual evolution from chaos to order and the transformation of aquatic species to terrestrial species by adaptation.

In the fourth century B.C., Empedocles believed that plants were evolved before animals and that imperfect forms arose by random combinations and were gradually replaced by perfect forms through the extinction of those which could not support themselves and multiply.

In the third century B.C., Aristotle attributed all evolutionary changes to natural causes. He rejected the hypotheses of their fortuitous origin and the survival of the fittest, and favoured the idea of intelligent design in the formation of adaptive characters. He graded evolution in a linear series from plants, sponges, sea-anemones and animals up to man. He anticipated Harvey's doctrine of epigenesis in development and duly noted the facts of heredity, dominance and reversion. In the first century B.C., Lucretius the poet followed Empedocles and ignored

Aristotle, he believed that structure preceded function as a random variation, and inferred the existence of heredity bodies within the mother. Aristotle's views of evolution, however, held the field for over two thousand years and were revived by Francis Bacon in the sixteenth century of our era. Bacon also added new ideas of the mutability of species by the accumulation of variations and large mutations and believed that new species arose from old species by a process of degeneration.

It is now apparent that the ecclesiastical opposition to Darwin in the last century was largely due to the unconscious influence of Aristotle's teaching which had persisted throughout the Dark Ages and was handed on indirectly through the early theologians.

In the eighteenth century, ideas of evolution became more prominent. Buffon believed in the influence of the environment in modifying the structures of animals and plants and in the inheritance of these acquired characters. He also emphasised the struggle for existence among animals and plants.

Born in the same year, the great systematist Linnaeus apparently believed in the special creation of genera, but thought that species and varieties originated by hybridisation between different genera. In the same period Bonnet expounded the novel idea that the Creation described in Genesis was only a resurrection of animals previously existing.

It was about this time that Erasmus Darwin, the grandfather of Charles Darwin, anticipated Lamarck in his ideas of the internal origin of adaptive characters. He thought that animal species were transformed by their own exertions in response to pleasure and pain and that many of these propensities were transmitted to posterity. He recognised the beneficial struggle for existence which checked too rapid increase of life. He was the first to make clear that organic evolution had persisted for millions of years and that all life arose from one primordial protoplasmic mass.

The similar views of his contemporary Lamarck had a much wider influence at that time and have even survived to this day. Early in the nineteenth century Geoffrey St Hilaire strongly supported the idea that evolution was caused by the direct action of the environment inducing profound changes in the egg, thus anticipating Weismann's idea of germinal variations. St Hilaire also believed that new species might be formed in this way from sudden large variations in one generation, thus anticipating the mutations of de Vries.

The way was therefore well prepared for the work of Charles Darwin who in 1859 in his *Origin of Species* was the first to provide an adequate proof of the facts of evolution and whose theory of natural selection is now accepted by biologists as a primary law of nature. Darwin was the first evolutionist to employ the inductive method of research by first observing and collecting facts and from these constructing working hypotheses to fit them. No one man, before or since, has amassed so many facts and observations as Darwin did and the sheer weight of the evidence he produced was so convincing that it overwhelmed all opposition to his views of evolution. Darwin's chief contribution was his law of natural selection which may be briefly stated as follows:

(1) Individuals of a species vary at random in many directions.

(2) These variations are transmitted to offspring.

(3) Those individuals which vary in a more favourable direction, fitting them to live in changed conditions, survive and multiply in larger numbers.

(4) Consequently in each generation there is a slow but definite approach to complete adaptation to different conditions of life.

(5) In secular time, as conditions change considerably, new species evolve and become established which are adapted to the new conditions and in this way evolution becomes an orderly procession of species adapted to the varied and variable conditions of life such as we find in Nature.

During and since the time of Darwin there have been many attempts to replace his law of natural selection with alternative theories of evolution. These have taken on Protean forms but most of them have a common basis in postulating with Aristotle, Erasmus Darwin, Goethe and Lamarck, that variation is not indeterminate in many directions, as Darwin found, but determinate in definite directions according to the needs of the species. In other words, orthogenesis replaces natural selection in the evolution of adaptations and species. Examples of modern orthogenetic theories are found in Carl von Nägeli's inner principle of progressive development, Eimer's orthogenesis, Cope's bathmism and kinetogenesis, Driesch's entelechy or vitalism, Bergson's *Élan vital* or the urge of life to creative evolution, and most recent of all, Berg's nomogenesis which may be described as a form of internal predestination. It will be observed that all these orthogenetic theories from Aristotle and Lamarck to Bergson and Berg, involve a mystical factor or principle which, in so far as it is incapable of experimental identification and verification, is beyond the province of science and must therefore, so far as biology is concerned, be regarded as purely speculative and relegated to the realm of metaphysical philosophy where it may be more usefully discussed. Incidentally it may be pointed out that the scientific mechanism of the chromosomes and genes expounded in this book goes far to explain a large number of the facts commonly attributed to the principle of orthogenesis by systematists, palaeontologists and embryologists.

On the whole the definite opponents of Darwinism among biologists are a small minority. Naturally with the progress of knowledge many new facts have come to light since the publication of Darwin's *Origin of Species* and considerable modifications and adjustments of Darwin's early views have been necessary. These modifications at the time appeared to be in direct opposition to Darwin's views, but as time passed it became more and more evident that these modifications have served to strengthen Darwin's original position. Space will allow only a few of these to be mentioned. For instance, Weismann supported the idea of natural selection but showed conclusively in his theory of the germ plasm that acquired characters are not as a rule inherited, as was assumed by Lamarck and Darwin and their contemporaries. Johannsen experimentally demonstrated the difference between fluctuating varieties or modifications which are not inherited and germinal variations or mutations which are. It may be pointed out, however, that although fluctuating modifications and acquired characters do not appear to be specifically inherited as such, yet they are potentially inherited, since they usually represent different reactions of the same gene complex in different environments and tend to be repeated in the same environment.

Bateson, with his critical and sceptical mind which sifted everything, was one of the first to realise the discontinuous nature of species and the difficulties of Darwinism, yet in the end Bateson's work in creating the new science of genetics and developing Mendelian experiments in plants and animals, paved the way for the new genetical Darwinism which has already thrown so much light on the nature of species and evolution.

The genetical approach to Darwinism has been further strengthened by the mathematical work of Fisher and Haldane, which has placed the study of natural selection on a higher plane, and has provided a new tool and approach to the problem, from which much is expected during the next decade. Fisher's work on *The Genetical Theory of Natural Selection*, with its new views of the origin of dominance and the natural selection of genotypes, has already become a classic. J. B. S. Haldane's *Mathematical Theory of Natural Selection* shows that in evolution, neither mutation nor Lamarckian transformation can prevail against natural selection of even moderate intensity. In America, Sewall Wright has also made an extensive mathematical investigation of the problem of evolution and natural selection, and in the main his results agree with those of Fisher and Haldane although he attaches more importance to random survivals in medium-sized populations than either Fisher or Haldane.

Darwin and Wallace both made some notable contributions to the important question of the geographical distribution of species and the evidence it provides for natural selection. Since their time this problem has been dealt with on a large scale both by Willis and by Vavilov. Willis in his *Age and Area* believes that a new species often arises from an old one by a sudden process of mutation of many characters and that although it survives by natural selection, yet natural selection is not a cause of the new species appearing. He presents important statistical evidence that rare plant species of restricted habitat are of recent origin and estimates that in the case of flowering plants about two species per century arise suddenly as new mutations. On Willis's theory each new species forms a centre of distribution and its area of distribution increases with the age of the species. Genetical experiments with Willis's rare and abundant species of a single genus (*Coleus*), that grow side by side, would no doubt solve the problem of their origin and test his theory which is supported by a general survey (statistically treated by Yule) of plants and animals in widely scattered areas and islands.

Confirmation of Willis's theory of *Age and Area* is also found in the remarkable work of Vavilov who has investigated the origin and distribution of the varieties of many species on an enormous scale in different continents. Like Willis he finds that species originate in primary and secondary centres and gradually extend their areas. This applies to both wild and cultivated species and varieties. He finds that dominant genes are concentrated in the centres of distribution while recessive genes are more prevalent around the periphery of the area. Vavilov and his army of Russian geneticists have already tested a large number of genes in these varieties in a large number of species from different parts of the world and in a few years a harvest of results should follow which will throw considerable light on the evolution of species. Another aspect of the problem of distribution and origin is found in some interesting statistical studies of thirty-five species of night-flying moths which have been carried out by Fisher and Ford and which show that species that are abundant are more variable than those that are rare. Rare species tend to decline and abundant species to increase. The explanation seems to lie in the rarity of advantageous mutations, which have a greater chance of establishing themselves if the breeding population is large. A large number of less abundant species will generally be decreasing, while a smaller number of those more abundant will be increasing, the total number of species being maintained by fission of the more abundant rather than of the less abundant types. The extensive work of Turrill in the geographical distribution of species in conjunction with the genetical experiments of Marsden-Jones has proved to be of primary importance in increasing our general knowledge of the nature and genic constitution of genetical species.

Many attempts have been made to supplement Darwin's law of natural selection and to clear up the outstanding difficulties in Darwin's views of heredity and variation. In the nineteenth century Mendel, Bateson, de Vries, Miss Saunders and a few others, foresaw that the only way to achieve this was by experimental investigations on strict scientific lines. From these small beginnings the new science of genetics arose in the first decade of the present century and in the course of thirty years it has completely revolutionised biological thought and has established research in evolution on the experimental basis of an exact science. The incorporation by Morgan, at an early stage, of the branch of cytology known as karyology, was an inspiration, since it has provided a new approach to the experimental study of evolution which has brought about the experimental demonstration of the living mechanism of heredity, variation and creative evolution. The concept of a genetical species experimentally based on combined studies in taxonomy, cytology and genetics has provided a unit of creative evolution and foreshadowed a new taxonomy based on genetical experiments.

The genetical creation of a new species of *Nicotiana* in 1925 by Clausen and Goodspeed and the similar creation of a new genus *Aegilotricum* in 1926 by Tschermak and Bleier, opened a new era in the experimental study of species and evolution.

The experimental creation by X-radiation of mutational and transmutational forms of *Drosophila* by Muller in 1927 proves to be another landmark in creative evolution, the ultimate issue of which cannot yet be estimated.

During the last few years much valuable cyto-genetical work has been done at the John Innes Horticultural Institution at Merton under the able leadership of Sir Daniel Hall, and systematic investigations of the species of *Rosaceae*, *Liliaceae* and other large families are being made.

The object of this book is to point out the salient features of these recent genetical discoveries and to show that the mechanism of the chromosomes and the genes therein is the mechanism of creative evolution.