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EVOLUTION

ITS NATURE, ITS EVIDENCES, AND ITS RELATION TO RELIGIOUS THOUGHT

BY

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PREFACE TO THE SECOND EDITION.

The three years which have elapsed since the publication of the first edition of this work have been years of great activity of thought on many of the subjects treated therein. Some changes and additions seemed therefore imperatively called for.

For example: There has sprung up recently among the foremost writers on evolution a warm discussion on the *factors* of evolution, their number and relative importance. I have therefore added a chapter ([Chap. III, Part II](#)) on this subject—not, indeed, to discuss it fully (for this would be impossible in the limits of a chapter), but to put the mind of the reader in position to understand it and to judge for himself.

Again: Every reader of the first edition must have remarked that there are many fundamental religious questions which I have not touched at all in [Part III](#). I had avoided these because my own mind was not yet fully clear. I regarded what I then wrote as only a little leaven in a very large lump. I was willing to wait and let it work. In the mean time it has worked in my own mind, and I hope in the minds of others. I have therefore added two chapters to this part. In one I simply carry out to their logical consequences the doctrine of the Divine Immanency. This brings up the questions of *First and Second Causes*; of *General and Special Providence*; of the *Natural and the Supernatural*; of *Mind vs. Mechanics in Nature*, etc., and shows the necessary changes of view which are enforced by the theory of evolution.

iv

In the other I take up very briefly “*The Relation of Evolution to the Doctrine of the Christ*.” In the discussion of this I restrain myself strictly within the limits of the subject as stated above.

The only other important changes are in [Chapter IV, Part III](#), “*On the Relation of Man to Nature*.” As I regard this as the most important chapter in the whole book, I have endeavored still further to enforce my view of the origin of man’s spirit, and especially to make it clearer by means of several additional illustrations.

JOSEPH LE CONTE.

BERKELEY, CAL., *July 1, 1891.*

v

PREFACE TO THE FIRST EDITION.

The subject of the following work may be expressed in three questions: What is evolution? Is it true? What then? Surely, there are no questions of the day more burning than these. Much has been written on each of them, addressed to different classes of minds: some to the scientific, some to the popular, and some to the religious and theological; but nothing has yet appeared which covers the whole ground and connects the different parts together. Much, very much has been written, especially on the nature and the evidences of evolution, but the literature is so voluminous, much of it so fragmentary, and most of it so technical, that even very intelligent persons have still very vague ideas on the subject. I have attempted to give (1) a very concise account of what we mean by evolution, (2) an outline of the evidences of its truth drawn from many different sources, and (3) its relation to fundamental religious beliefs. I have determined, above all, to make a book so small that it may be read through without much expense of time and patience. But the subject is so large that in order to do so it was necessary to sacrifice all but what was most essential, and to forego all redundancy (the bane of so-called popular science) even at the risk of baldness and obscurity. Nevertheless, I hope that the first and second parts will be found not only interesting to the intelligent general reader, but even profitable to the special biologist. I have tried to make these parts as untechnical as possible, but I hope not on that account the less scientific. For I am among these who think that it is not necessary to be superficial in order to be popular—that science may be adapted to the intelligent popular mind without ceasing to be science.

vi

The third part seems to me still more important just now. There is a deep and widespread belief in the popular mind, and even to some extent in the scientific mind, that there is something exceptional in the doctrine of evolution as regards its relation to religious thought and moral conduct. Other scientific theories have required only some modifications of religious conceptions, but this utterly destroys the possibility of all religious belief by demonstrating a pure materialism. Now this, I believe, is a complete misconception. Thinking men are fast coming to see this; some, indeed, have mistaken the change for a reaction against evolution. It is a reaction not against evolution, but only against its materialistic implication. Evolution is more and more firmly established every year. The tide of conviction is one which knows no ebb. Some clear statement, in brief space, of its true relation to religious thought seems, therefore, very important at this time.

BERKELEY, CAL., *May, 1887.*

vii

CONTENTS.

PART I.

WHAT IS EVOLUTION?

CHAPTER I.

ITS SCOPE AND DEFINITION.

PAGE

<i>A type of evolution</i> —Development of an egg	3
<i>Universality of evolution</i> —Pervades all nature and concerns all departments of thought—One half of all science—Illustrated (1) by human body, (2) by solar system, (3) by society, (4) by earth, (5) by organic kingdom—The term evolution usually, but not rightly, confined to this last	3
<i>Definition of evolution</i> — <i>I. Progressive change</i> —Shown in the animal body, or the <i>Ontogenic</i> series—In the animal scale, or the <i>Taxonomic</i> series—In the geological, or <i>Phylogenic</i> series—The three series similar, though not identical	8
<i>II. Change according to certain laws</i> —Three laws of succession of organic forms	11
(a) <i>Law of differentiation</i> —Early forms are generalized; afterwards separated into specialized forms—Illustrated by fishes, by birds—Whole process of differentiation illustrated by growth and branching of a tree	11
(b) <i>Law of progress of the whole</i> —Mistake of confounding evolution with upward progress—How far true, and how far false—Illustrated by branching tree—Examples of this mistake in the popular mind—In the scientific mind	13
(c) <i>Law of cyclical movement</i> —Shown in geological history—Age of mollusks, fishes, reptiles, mammals, man—Illustrated again by a branching tree—Increasing complexity as well as height—Illustrated by diagram	16
<i>The above three laws are laws of evolution</i> — <i>Differentiation</i> —Shown in the development of an egg, the type of evolution	19
<i>Progress of the whole</i> —Not progress of all parts—Shown in the development of an egg	22
<i>Cyclical movement</i> —Less fundamental than other two—Shown in Ontogeny of body, of mind—Increasing complexity—Necessity of continued advance—Otherwise deterioration—All these laws shown in progress of society—Differentiation shown—Progress of the whole but not of all parts shown—Cyclical movement shown—In social evolution, however, there is another element, viz., conscious voluntary progress—This kind of evolution contrasted with the other	22
<i>III. Change by means of resident forces</i> —This is the point of dispute—Sense in which we use term resident forces—Does not touch question of origin of natural forces	27

viii

The two views of the origin of organic forms briefly contrasted—As to whether natural or supernatural—As to variability, definite or indefinite—As to change from one species to another by transmutation or substitution—As to universality of law of continuity [29](#)

CHAPTER II.

THE RELATION OF LOUIS AGASSIZ TO THE THEORY OF EVOLUTION.

General misunderstanding on this subject—Necessary to give sketch of history of the idea—Greeks, Lucretius, Swedenborg, and Kant—First scientific presentation by Lamarck—General character of Lamarck's views—Failed, and rightly so—Next, Chambers's "Vestiges of Creation"—Its general character—Failed, and rightly so—Some think this unfortunate—Why not so—An obstacle must be removed and a basis laid [32](#)

The obstacle removed—Old views in regard to forces—Correlation of forces established—But vital force considered exception—Therefore living forms also supposed exception to mode of origin of other forms—Then vital forces also correlated—Therefore, *a priori* probable that living forms also correlated with other forms as to mode of origin—Thus obstacle removed [35](#) ix

The basis laid—Agassiz laid inductive *basis* of evolution, although he refused to build—He established the laws of evolution and perfected the method of comparison—Importance of method discussed—The method of *notation*—The method of experiment—The difficulty of applying these to life phenomena—Method of comparison shown—(1) In Taxonomic series—(2) In Ontogenic series—(3) In Phylogenic series—Cuvier the great worker by comparison in the Taxonomic series—Agassiz in the Ontogenic and Phylogenic—Agassiz also established the three laws of evolution given in previous chapter—Thus he laid foundation—Why he did not build—Supposed identity of evolution and materialism—The obstacle being removed and the basis laid, when evolution again brought forward it was universally accepted, because the world was prepared—Place of Agassiz and Darwin compared—Formal science vs. physical science—Illustrated by relation of Kepler to Newton—Relation of Agassiz to time cosmos similar to that of Kepler to space cosmos—So Darwin to Newton—Some reflections on the above—Gravitation is the law of space cosmos—Evolution of time cosmos—Of the divine spherulic music gravitation is the chordal harmony and evolution the melody [37](#)

PART II.

EVIDENCES OF THE TRUTH OF EVOLUTION.

CHAPTER I.

GENERAL EVIDENCES OF EVOLUTION AS A UNIVERSAL LAW.

Evolution is continuity, causal relation, gradual becoming—Increasing acceptance of this idea—First accepted for inorganic forms, mountains, continents and seas, rocks and soils, earth as a whole, heavenly bodies—Therefore acknowledged for all inorganics—Influence of geology in bringing about this change—Organic forms: acknowledged for individuals, true for classes, orders, families, genera—Races and varieties also formed gradually—Artificial species formed gradually—Examples of gradual changes in wild species—Hyatt's researches—Other examples—Summing up of general evidence—Sufficient ground for induction—But evolution is not only [53](#) x

inductively probable but certain, axiomatic—It is the law of causation applied to forms, and therefore a necessary truth

CHAPTER II.

SPECIAL PROOFS OF EVOLUTION.

Introductory.

Special proofs necessary—Evolution, though certain, is not yet accepted by the popular mind—
Different departments from which proofs are drawn [67](#)

Origin of new organic forms; the old view briefly stated—Necessary to give a brief statement of theories—Old view—Permanency of specific types—Supernatural origin of species—Centers of creation—Explanation of facts of geographical distribution—Of geological distribution—Modification of extreme view—Variability, but within limits—Illustrated [68](#)

The new view briefly stated—Indefinite variability of organic forms—Effect of environment on rigid forms—On plastic forms—Taxonomic groups represent degrees of kinship [72](#)

Factors of evolution—(1) Physical environment—(2) Use and disuse of organs—(3) Natural selection—(4) Sexual selection—(5) Physiological selection—Its necessity shown—Its operation explained—Compared with natural selection—Cause of variation unknown—Explanation of this is the next great step in the theory of evolution [73](#)

CHAPTER III.

THE GRADES OF THE FACTORS OF EVOLUTION AND THE ORDER OF THEIR APPEARANCE.

Factors of evolution restated; their grades and the order of their introduction shown—Lamarckian factors, first in order because they precede sexual reproduction—(1) Environment—(2) Use and disuse—With sexual reproduction selective factors introduced—(3) Natural selection—(4) Physiological selection—(5) Sexual selection—With man was introduced (6) the rational factor—In this process two striking stages—viz., the introduction of sex and the introduction of reason—Effect of each to hasten the steps of evolution—The last by far the greater change [81](#)

Contrast between organic and human evolution—(1) The meaning of term *fittest* in each—(2) Destiny of the weak and helpless in each—(3) The nature of evolutionary transformation in each—(4) The law of strait and narrow way applied in each—(5) Human evolution is a different kind and on a higher plane [88](#)

Application to some questions of the day.

I. Neo-Darwinists, their position explained—Reasons for dissenting—(a) Lamarckian factors preceded all others—(b) Though now subordinate, they still underlie and condition all other factors—(c) Shown by comparison of phylogeny with ontogeny [92](#)

II. Human progress not identical with organic evolution—Mistake of the materialists—But neither is it wholly different, as some suppose [96](#)

III. Neo-Darwinism is fatal to hopes of human progress—Reason may use freely Lamarckian factors, but can not use natural selection in the same way as Nature does [97](#)

CHAPTER IV.

SPECIAL PROOFS FROM THE GENERAL LAWS OF ANIMAL STRUCTURE, OR COMPARISON IN THE TAXONOMIC SERIES.


General Principles.

Analogy and homology—Defined and illustrated by examples—Wings and limbs—Lungs, gradual formation of, traced in the Taxonomic series—Traced in the Ontogenic series—Examples of homology in plants: tuber, cactus-leaf, acacia-leaf—Definitions repeated and further explained—Common origin is the only explanation of homology [99](#)

Primary divisions of the animal kingdom—True ground of such divisions is ability to trace homology—We take examples only from vertebrata and articulata—Compare to styles of architecture—To machines—To branching stem [107](#)

CHAPTER V.

PROOFS FROM HOMOLOGIES OF THE VERTEBRATE SKELETON.

Common general plan—In several respects—Strongly suggestive of common origin—Details of structure demonstrative of the same [111](#) 

Special homology of vertebrate limbs [113](#)

Fore-limbs—Comparison of fore-limbs of mammals, birds, reptiles, and fishes, part for part—Gradual changes in collar-bone and coracoid—In position of elbow—In bones of forearm—In position of wrist—In the tread—The term manus—Number of toes—Modifications for flight in various animals—For swimming in whales and fishes [113](#)

Hind-limbs—Comparison of hind-limbs of several mammals—Position of knee—Of heel—Plantigrade and digitigrade—Degrees of the latter—Number of toes—General law in regard to number of similar parts—Order of toe-dropping in artiodactyles—In perissodactyles [121](#)

Genesis of the horse—Changes in foot-structure—Same true of other parts of skeleton—Only natural explanation is derivation—Nature compared with man in mode of working—Angels—Griffins—Centaur—Muscular and nervous systems—Visceral organs [126](#)

CHAPTER VI.

HOMOLOGIES OF THE ARTICULATE SKELETON.

Illustrations from this type—Plan of structure entirely different—General plan of structure explained and modifications shown—Shrimp—Modification of segments and of appendages for various purposes: swimming, walking, eating, sense—Illustrated by other crustaceans—By myriapods—By marine worms—Crabs—Embryonic development of crabs—insects—Modification of segments and appendages—Mouth parts of insects [132](#)

Illustration of the law of differentiation—Cells—Segments—Individuals—Homologies in other departments of animals, but these are less familiar—Between primary groups, homology [144](#)

untraceable in adult forms—But these also probably connected by common origin—Different views as to origin of vertebrates

CHAPTER VII.

PROOFS FROM EMBRYOLOGY, OR COMPARISON IN THE ONTOGENIC SERIES.

- Resemblance of the three series*—Frog, in Ontogeny passes through main stages of Taxonomy and Phylogeny—Resemblance only general—Many steps dropped out in Ontogeny 148 xiii
- (1) *Ontogeny of tailless amphibians*—The frog: fish stage, perennibranch stage, caducibranch stage, aneural stage—Same stages in Phylogeny 150
- (2) *Aortic arches*—Those of lizard described—Origin from gill-arches of fish—Change from one to the other in Ontogeny of a frog—Same changes in Phylogeny of lizard—Embryonic condition of mammalian heart and vessels—Gradual change and final condition in birds—In mammals—Gradual decrease in number of aortic arches as we go up the vertebrate scale—Cogency of the argument from aortic arches 151
- (3) *Vertebrate brain*—Fish brain—Brain of reptiles, birds, mammals, man compared—Human brain passes through similar stages—Changes in complexity of structure in Taxonomy—Same changes in Ontogeny of mammals—Same in Phylogeny of reptiles, birds, mammals 162
- Cephalization*—Explanation of, in body, in mind 171
- (4) *Fish-tails*—Homocercal and heterocercal—Vertebrated and non-vertebrated—Order of change in Ontogeny—Same in Phylogeny—Similar changes in birds' tails in Ontogeny and Phylogeny—In other tailless animals—Examples from articulates, insects, crustaceans, etc. 172
- Illustration of the differentiation of the whole animal kingdom*—Development of eggs of all kinds of animals—This a type of changes in Phylogeny—Why Ontogeny repeats Phylogeny—Law of acceleration 176
- Proofs from rudimentary and useless organs*—Examples from whale: Teeth—Limbs—Hair—Olfactive organs—Examples from man: muscles, cæcal appendage—Significance of useless organs 179

CHAPTER VIII.

PROOFS FROM GEOGRAPHICAL DISTRIBUTION OF ORGANISMS.

- Geographical faunas and floras*—Conditions which limit 183
- Temperature-regions*—Illustrated by plants—In latitude and in elevation—Same in animal species 184
- More perfect definition of regions*—Range of different Taxonomic groups—Gradual shadings on borders of range—Shadings out of individuals in number and vigor, but not in specific character—As if centers of origin—Effect of east and west barriers—Temperature regions repeated south of the equator, but not species—As if centers of origin 186 xiv
- Continental faunas and floras*—Temperature zones continuous, but not species—Reason: ocean barriers—As if centers of origin—Polar regions: one. Why—Temperate zone—Different species in different continents—Species of United States and of Europe almost wholly different—As if origin local—Exceptions—(1) Introduced species—(2) Hardy or else wide-migrating species— 188

(3) Alpine species—Tropical zone of two continents still more different—Same true of south temperate zone	
<i>Subdivisions of continental faunas and floras</i> —Illustrated by fauna and flora of United States	191
<i>Special Cases</i> —Australia—Madagascar—Galapagos—River mussels	192
<i>Marine species</i> —Same principles applicable—Therefore organic forms grouped in regions, sub-regions, provinces, etc.—Primary regions according to Wallace—According to Allen	192
<i>Theory of the origin of geographical diversity</i> —Specific centers of creation—Objections to. The element of time left out—Progressive change in unlimited time, or evolution the only rational explanation—This connects with geographical changes in geological times, especially the Glacial epoch—Geographical diversity in other times	193
<i>Most probable view of the general process</i> —Last great period of change was the Glacial epoch—This, therefore, is the key to geographical distribution—Condition of things during the Glacial epoch—In America—Changes in temperature—In physical geography and in species—In Europe—Application of principles	196
(1) <i>Australia</i> —Characteristics of its fauna—Explanation of—Isolation very early—Position of marsupials and monotremes in the Taxonomic scale—Australia isolated before the Tertiary—Effect of competition on evolution	200
(2) <i>Africa</i> —African region defined—Two groups of its mammals, indigenes, and invaders—Effect of the invasion	204
(3) <i>Madagascar</i> —Characteristics of its fauna—Relation to African indigenes—Separated before the invasion—Significance of its lemurs	205
(4) <i>Island life</i> —Two kinds of islands—Defined and illustrated by examples—(a) <i>Continental islands</i> —General character of fauna—Illustrated by Madagascar, New Zealand, British Islands, coast-islands of California—Characteristics of the faunas of these explained—(b) <i>Oceanic Islands</i> —Defined—Characteristics of faunas and their origin	207
(5) <i>Alpine species</i> —Characteristics of and their origin explained—Migrations of Arctic species during Glacial times, and their isolation on mountains	215
<i>Objection</i> —Mode of change of species on borders of ranges—Examples—Sweet-gum—Sequoia	217
<i>Answer</i> —Distribution of these forms in time, and their migrations—They are remnants—Intermediate forms are extinct	219

[CHAPTER IX.](#)

PROOFS FROM VARIATION OF ORGANIC FORMS, ARTIFICIAL AND NATURAL.

<i>Limitation of the use of experiment in morphology</i> —Unconscious experiments in breeding, and their results—Principles involved—Inheritance, immediate and ancestral—Effect of true breeding long continued—Method of selection illustrated by diagram—Formation of a race—Process the same in nature—Show selective effect of physical environment—Of organic environment—Of migrations—Of unlimited time—Other factors of change, and their effects shown in nature and in domestication—Differences between artificial and natural species	222
<i>First difference, reversion</i> —The tendency to reversion described—The reason explained—Illustrated by the case of the pointer	229

Second difference, intermediate forms—Reason is, these are eliminated in nature [232](#)

Third difference, cross-fertility—Natural species are usually cross-sterile—Degrees of cross-sterility—Two bases of species, morphological and physiological—Two kinds of isolation, sexual repugnance and cross-sterility—Latter most essential—Illustrated by plants and hermaphrodite animals—Former only higher animals—Natural laws interfered with by domestication—Illustrated by plants and animals [232](#)

Law of cross-breeding—Effect of close breeding—Of crossing varieties to a limit—The law investigated—Reproduction in lowest organisms—Fission—Gemmation—Internal gemmation—Sex introduced—Effect of, is funding of differences in offspring and tendency to variation—Sexual and non-sexual reproduction compared—Separation of sex elements—Of sex-individuals—Introduction of sex-attraction—Funding of greater differences in offspring—Crossing of varieties—Diagram illustrating effect in vigor—Effect also in plasticity—Application of these principles—Necessity of sexual isolation to produce species—Origin of cross-sterility and thus of species by Dr. Romanes's idea—Why artificial varieties are cross-fertile—Geographical species sometimes cross-fertile—Application of principles—Absence of intermediate links in natural species explained—Under what conditions such are found—Further explanation of this point—Illustrated by a growing tree [236](#)

Objection answered—Intermediate links ought to be found fossil—Answer (1) Imperfection of record. (2) The term species indefinite. (3) Transitions between all other taxonomic groups abundant. (4) Between species, also, both living and fossil—Of fossil, Planorbis of Steinheim—Other examples—(5) Why transition-forms are rare—Answer—Changes in every department of nature are paroxysmal—Illustrated—So the steps of evolution paroxysmal—Critical periods in evolution—Causes of rapid advance—Apparent discontinuity between species—(1) changes paroxysmal—(2) Brooks's idea—Male sex is the progressive element—Illustrated by society—Effect of prosperous times—Mrs. Treat's experiments—Hard times produce excess of males, and therefore tend to diversity—Summary [248](#)

Objection—Egyptian drawings and mummy plants, show no change—Answer (1) Time too short. (2) We are now in time of slow change. (3) All species don't change, most become extinct. (4) Evolution is probably slower now than formerly—Reasons for so thinking—Organic evolution approaching completion—Other supposed objections [265](#)

Origin of beauty—Explanation of, in higher animals—In flowering plants—But in many cases we can't explain [269](#)

Incipient organs—Difficulty of explaining—But these are not objections to the *fact* of evolution, but only to the sufficiency of the present *theories* of evolution. Therefore, all discussion concerns special theories. The fact of evolution is certain [270](#)

PART III.

THE RELATION OF EVOLUTION TO RELIGIOUS THOUGHT.

CHAPTER I.

INTRODUCTORY.

Evolution if true affects every department of thought—What will be its effect on religious beliefs?—Objection that truth-seeker has nothing to do with effects—Answered [275](#)

Relation of the true and the good [277](#)

Relation of philosophy to life—The three necessary elements of a rational philosophy—Application to the case in hand—And the subject of Part III justified—Exaggerated fears—Different forms of the conflict of science and religion—(1) Heliocentric theory—First effect and final result—(2) Law of gravitation—Effect and result—(3) Antiquity of the earth and cosmos—Effect and result—(4) Antiquity of man—(5) Evolution [277](#)

CHAPTER II.

THE RELATION OF EVOLUTION TO MATERIALISM.

Supposed identity—Tendency of the age—Evolution does not differ in this regard from other laws of Nature—Absurdity of identification illustrated in many ways—(1) Effect of discovery of process of making—(2) Effect of new form of old truth—(3) Manner in which vexed questions are settled and rational philosophy found—Illustrated—A true philosophy is a reconciliation of partial views—Three possible views of origin of individuals and of species; two one-sided and partial, and the third combining, reconciling, and therefore rational—The only bar to speedy reconciliation is dogmatism—Theological and scientific—The appropriate rebuke for each—Therefore evolution does not differ from other laws in regard to its relation to materialism—Nevertheless, great changes in our traditional beliefs impending—Main changes are notions concerning God, Nature, and man, in their relations to one another [284](#) xviii

CHAPTER III.

THE RELATION OF GOD TO NATURE.

The issue in regard to this relation stated—The growth of the issue described—The old view of direct relation—The effect of science and the resulting view—The compromise—Destroyed by evolution—The issue forced—The alternative view—Immanence of Deity—This view explained—Objection of idealism—Answered—It is not subjective idealism—Objection of pantheism—Answer deferred—Objection that the view is incompatible with practical life—Answered [297](#)

CHAPTER IV.

THE RELATION OF MAN TO NATURE.

The two extreme views in this regard—They are views from different points, psychical and material—The latter very productive in modern times—But many fear the final effect—Reconciliation is possible—Scientific materialism has two branches—*Physiological branch* explained—Conclusion—Answer—Relation of psychic to brain changes is inscrutable—The mystery illustrated—Outside and inside view—Different from other phenomena in this regard [304](#)

Evolution branch—Close relation of man to animals—Therefore must extend immortal spirit to animals—to plants—to all existence, and thus identify immortality with conservation of force—Embryonic series—Where did spirit enter?—Evolution series—Where did spirit enter?—Answer—Derived from Nature—The true view of origin stated—Show that it is not in discord with other phenomena of evolution—The five planes of matter and of force—The change from one to another not gradual now nor in the evolution of natural forces—Consecutive births into higher forms—Every step of these changes taking place now—Relation of these facts to [311](#)

immortality—The process briefly stated—Omnipresent divine energy individuated to separate entity in man—Anima of animals is spirit in embryo—Came to birth in man—Illustrated in other ways—(1) By more or less completed water-drop—(2) By submergence and emergence—(3) By planet birth—(4) By physical birth—(5) By grades of organic individuality—(6) By the body as an instrument of communication between two worlds—Self-consciousness the sign of spirit-individuality—Any animal conscious of self would be immortal—Similar changes in passing from animals to man in all other departments of psychic activity—Objection that other changes of energy not permanent; answered—Our view of origin compared with alternative views—Plato's view—Orthodox view

xix

Some general conclusions—(1) Two series of changes, brain-changes and mind-changes—The initiative in animals—In man—(2) Justification of term "*vital principle*"—Becomes entity in man—(3) This view is a complete reconciliation of realism and nominalism—(4) No meaning in Nature without spirit—And no meaning in geological history without derivative origin of spirit—Material evolution finds its goal in man, psychic evolution in the divine man

[327](#)

[CHAPTER V.](#)

THE RELATION OF GOD TO MAN.

Question of revelation—Difficulty of the subject—Operation of divine spirit on spirit of man more direct than on Nature—This is revelation—This is no violation of law, but operation by higher law—Term supernatural is relative—Illustrated—There is but one kind of revelation, and this to all men in different degrees—Always imperfect, and therefore must be tried by reason

[331](#)

[CHAPTER VI.](#)

THE OBJECTION, THAT THE ABOVE VIEW IMPLIES PANTHEISM, ANSWERED.

The objection stated and the general answer—In deepest questions single lines of thought lead to extreme views—Must follow other lines—These lead to personality

[335](#)

(1) Exact character of relation of God and of necessary law to man's freedom is inscrutable

[338](#)

(2) On the inside of brain-changes we find personality—So on the inside of natural phenomena must also be person—In either case science studies the outside only—In Nature all is mechanics on the outside, but all is mind on the inside—Thought behind brain-changes compels belief in same behind natural phenomena—Law of infinite expansion—Illustrated by ideas of Space and Time—So also with idea of self—Infinite person inconceivable, but contrary is more inconceivable—Illustrated by ideas of Space and Time

xx

[338](#)

(3) Idea of *Causation* and of *Force*—Derived from *within*—Steps of the evolution of this idea—Final result is one infinite personal will—Expansion of idea of causal nexus between phenomena to the idea of one infinite cause

[342](#)

(4) Idea of *design* also originates *within*—Ineradicable, but changes form—Expands to infinity—Same change produced by science in all our notions concerning God—Same in our sense of *mystery*—Same in our notions concerning *creation*—Same in our conceptions of *design*—Thus, self-consciousness behind brain-changes compels belief in God behind Nature—The closeness of connection in the one case necessitates closeness of connection in the other—Every material change in Nature caused by a mental change behind Nature

[345](#)

CHAPTER VII.

SOME LOGICAL CONSEQUENCES OF THE DOCTRINE OF THE DIVINE IMMANENCY.

Religious thought subject to the law of evolution; three main stages 351

- I. *Conception of God*—The three stages shown—(1) Anthropomorphism—(2) Absentee landlordism—(3) Immanence [351](#)
- II. *Question of First and Second Causes*—The three stages shown here—(1) All is First Cause but man-like—(2) Distinction of first and second causes introduced—(3) Identification of these [354](#)
- III. *General and Special Providence*—The same three stages shown and the same outcome—viz., identification [355](#)
- IV. *Natural and the supernatural*—The same stages and the same final identification—Question of miracles [355](#)
- V. *Question of design or mind in Nature*—The same three stages and the same solution shown here—Confusion in the minds of modern writers [357](#)
- VI. *Question of mode of creation*—Old and new views contrasted [358](#)

CHAPTER VIII.

RELATION OF EVOLUTION TO THE IDEA OF THE CHRIST.

Comparison of organic with human evolution—The idea of the first is *man*, of the second is the *Christ*—Definition of the Christ as *ideal man*—The Christ ought to differ from us in a superhuman way—Shown by several illustrations—The Christ, as ideal man, a true object of rational worship—The ideal of organic evolution comes *at the end*—Ideal of human evolution must come *in the course*—Objection that there are many partial ideals answered—Relative vs. absolute moral ideal. [360](#)

xxi

CHAPTER IX.

THE RELATION OF EVOLUTION TO THE PROBLEM OF EVIL.

- The difficulty of the problem—The light on it by evolution—Evil must be based on the constitution of Nature and therefore universal—Some of its forms [365](#)
- (1) *Physical evil in animal kingdom*—Condition of organic evolution is struggle with an apparently inimical environment—In its course it seems evil—Looking back from the end it is good. [365](#)
 - (2) *Physical evil in relation to man*—Necessary condition of social evolution is also struggle with a seeming evil environment—But looking back from the end this evil is also seen to be good—Without it man would never have emerged from animality. [366](#)
 - (3) *Organic evil—Disease*—This also is the necessary condition of acquisition of knowledge of organic Nature—In the course of evolution it seems evil, but from the end it is seen to be good—In the physical world, laws of Nature are beneficent in their general operation, and only evil in their specific operation through our ignorance. [367](#)
 - (4) *Moral evil—Moral disease*—Difference between this and other forms of evil—Can this also [369](#)

be transmuted into good?—This is only the highest form of evil, and therefore subject to the same laws of evolution—Here also elevation comes only through knowledge and power, and these only through struggle with apparent evil—In course it seems evil, looking back from end it is seen to be good to the race—In all, therefore, the individual is sacrificed to the race, but impossible here—A way of escape found in the nature of a moral being—In this case not only final victory for the race, but also within the power of the individual—In this case success is in proportion to honest effort in right spirit—Roots, of evil in the necessary law of evolution—It is the necessary condition of all progress—Without it a moral being is impossible—From philosophic point of view things are not good and evil, but only higher and lower—All things good in their places—Evil is discord—Good is due relation—Action and reaction of higher and lower is the necessary condition of true virtue

PART I.

WHAT IS EVOLUTION?

CHAPTER I.

ITS SCOPE AND DEFINITION.

A Type of Evolution.—Every one is familiar with the main facts connected with the development of an egg. We all know that it begins as a microscopic germ-cell, then grows into an egg, then organizes into a chick, and finally grows into a cock; and that the whole process follows some general, well-recognized law. Now, this process is evolution. It is more—it is *the* type of all evolution. It is that from which we get our idea of evolution, and without which there would be no such word. Whenever and wherever we find a process of change more or less resembling this, and following laws similar to those determining the development of an egg, we call it evolution.

Universality of Evolution.—Evolution as a *process* is not confined to one thing, the egg, nor as a doctrine is it confined to one department of science—biology. The process pervades the whole universe, and the doctrine concerns alike every department of science—yea, every department of human thought. It is literally one half of all science. Therefore, its truth or falseness, its acceptance or rejection, is no trifling matter, affecting only one small corner of the thought-realm. On the contrary, it affects profoundly the foundations of philosophy, and therefore the whole domain of thought. It determines the whole attitude of the mind toward Nature and God.

4

I have said evolution constitutes one half of all science. This may seem to some a startling proposition. I stop to make it good.

Every system of correlated parts may be studied from two points of view, which give rise to two departments of science, one of which—and the greater and more complex—is evolution. The one concerns changes within the system by action and reaction between the parts, producing equilibrium and stability; the other concerns the progressive movement of the system, as a whole, to higher and higher conditions—the movement of the point of equilibrium itself, by constant slight disturbance and readjustment of parts on a higher plane, with more complex inter-relations. The one concerns the laws of sustentation of the system, the other the laws of evolution. The one concerns things as they are, the other the process by which they become so. Now, Nature as a whole is such a system of correlated parts. Every department and sub-department of Nature, whether it be the solar system or the earth, or the organic kingdom, or human society, or the human body, is such a system of correlated parts, and is therefore subject to evolution. We can best make this thought clear by examples:

1. Take, then, the *human body*. This complex and beautiful system of correlated and nicely-adjusted parts may be studied in a state of maturity and equilibrium, in which all the organs and functions by action and reaction co-operate to produce perfect stability, health, and physical happiness. This study is physiology. Or else the same may be studied in a state of progressive change. Now, we perceive that the stability is never perfect—the point of equilibrium is ever moving. By the ever-changing number and relative power of the co-operating parts the equilibrium is ever being disturbed, only to be readjusted on a higher plane, with still more beautiful and complex inter-relations. This is growth, development, evolution. Its study is called embryology. 2. Take another example—the *solar system*. We may study sun, planets, and satellites in their mutual actions and reactions, co-operating to produce perfect equilibrium, stability, beautiful order, and musical harmony. This is the ideal of physical astronomy as embodied in Laplace's "Mécanique Céleste." Or we may study the same in its origin and progressive change. Now, we perceive that equilibrium and stability are never absolutely perfect, but, on the contrary, there is continual disturbance with readjustment on a higher plane—continual introduction of infinitesimal discord, only to enhance the grandeur and complexity of the harmonic relations. This is the nebular hypothesis—the theory of the development of the solar system. It is cosmogony; it is evolution. 3. Again: *society* may be studied in the mutual play of all its social

5

6

functions so adjusted as to produce social equilibrium, happiness, prosperity, and good government. This is social statics. But equilibrium and stability are never perfect. Permanent social equilibrium would be social stagnation and decay. Therefore, we must study society also in its onward movement—the equilibrium ever disturbed, only to be readjusted on a higher plane with more and more complexly inter-related parts. This is dynamics—social progress. It is evolution. 4. Again: the *earth*, as a whole, may be studied in its present forms, and the mutual action of all its parts—lands and seas, mountains and valleys, rivers, gulfs, and bays, currents of air and ocean—and the manner in which all these, by action and reaction, co-operate to produce climates and physical conditions such as we now find them. This is physical geography. Or, we may study the earth in its gradual progress toward its present condition—the changes which have taken place in all these parts, and consequent changes in climate; in a word, the gradual process of becoming what it now is. This is physical geology—it is evolution. 5. Lastly, we may study the whole *organic kingdom* in its entirety as we now find it—the mutual relation of different classes, orders, genera, and species to each other and to external conditions, and the action and reaction of these in the struggle for life—the geographical distribution of species and their relation to climate and other physical conditions, the whole constituting a complexly adjusted and permanent equilibrium. This is a science of great importance, but one not yet distinctly conceived, much less named.¹ Or, we may study the same in its gradual progressive approach, throughout all geological times, toward the present condition of things, by continual changes in the parts, and therefore disturbance of equilibrium and readjustment on a higher plane with more complex inter-relations. This is development of the organic kingdom. In the popular mind it is, *par excellence*, evolution.

7

We might multiply examples without limit. There are the same two points of view on all subjects. As already said, in the one we are concerned with things as they are; in the other, with the process by which they became so. This “law of becoming” in all things—this universal law of progressive inter-connected change—may be called the law of continuity. We all recognize the universal relation of things, gravitative or other, in space. This asserts the universal causal relation of things in *time*. This is the universal law of evolution.

But it has so happened that in the popular mind the term evolution is mostly confined to the development of the organic kingdom, or the law of continuity as applied to this department of Nature. The reason of this is that this department was the last to acknowledge the supremacy of this law; this is the domain in which the advocates of supernaturalism in the realm of Nature had made their last stand. But it is wholly unphilosophical thus to limit the term. If there be any evolution, *par excellence*, it is evolution of the individual or embryonic development. This is the clearest, the most familiar, and most easily understood, and therefore the type of evolution. We first take our idea of evolution from this form, and then extend it to other forms of continuous change following a similar law. But, since the popular mind limits the term to development of the organic kingdom, and since, moreover, this is now the battleground between the advocates of continuity and discontinuity—of naturalism and supernaturalism in the *realm of Nature*—what we shall say will have reference chiefly to this department, though we shall illustrate freely by reference to other forms of evolution.

8

DEFINITION OF EVOLUTION.

Evolution is (1) continuous *progressive change*, (2) *according to certain laws*, (3) and by means of *resident forces*. It may doubtless be defined in other and perhaps better terms, but this suits our purposes best. Embryonic development is the type of evolution. It will be admitted that this definition is completely realized in this process. The change here is certainly continuously progressive; it is according to certain well-ascertained laws; it is by forces (vital forces) resident in the egg itself. Is, then, the process of change in the organic kingdom throughout geologic times like this? Does it correspond to the definition given above? Does it also deserve the name of evolution? We shall see.

9

I. Progressive Change.—Every individual animal body—say man’s—has become what it now is by a gradual process. Commencing as a microscopic spherule of living but apparently unorganized

protoplasm, it gradually added cell to cell, tissue to tissue, organ to organ, and function to function; thus becoming more and more complex in the mutual action of its correlated parts, as it passed successively through the stages of germ, egg, embryo, and infant, to maturity. This ascending series of genetically connected stages is called the embryonic or *Ontogenic* series.²

There is another series the terms of which are coexistent, and which, therefore, is not in any sense a genetic or development series, but which it is important to mention, because to some degree similar to and illustrative of the last. Commencing with the lowest unicelled microscopic organisms, and passing up to the animal scale, *as it now exists*, we find a series of forms similar, though not identical, with the last. Here, again, we find cell added to cell, tissue to tissue, organ to organ, and function to function, the animal body becoming more and more complex in structure, in the mutual action of its correlated parts, and the mutual action with the environment, until we reach the highest complexity of structure and of internal and external relations only in the highest animals. This ascending series may be called the natural history series; or, the classification or *Taxonomic series*.³ The terms of this series are, of course, not genetically connected; at least, not directly so connected. In what way they are connected, and how the series comes to be similar to the last, we shall see by-and-by.

Finally, there is still a third series, the grandest and most fundamental of all, but only recently recognized, and therefore still imperfectly known. Commencing with the earliest organisms, the very dawn of life, in the very lowest rocks, and passing onward and upward through Eozoic, Palæozoic, Mesozoic, Cenozoic, to the Psychozoic or present time, we again find first the lowest forms, and then successively forms more and more complex in structure, in the interaction of correlated parts and in interaction with the environment, until we reach the most complex internal and external relations, and therefore the highest structure only in the present time.⁴ This series we will call the geological or *phylogenic* series.⁵ According to the evolution theory, the terms of *this* series also are genetically connected. It is, therefore, an evolution series. Furthermore, it is the most fundamental of the three series, because it is the *cause* of the other two. The Ontogenic series is like it because it is a brief recapitulation, through heredity, as it were from memory, of its main points. The Taxonomic series is like it because the *rate* of advance along different lines was different in every degree, and therefore every stage of the advance is still represented in a general way among existing forms. Some of these points will be explained more fully in future chapters, in connection with the evidences of the truth of evolution.

It will be admitted, then, that we find *progressive change* in organic forms throughout geological times. This is the first point in the definition of evolution.

II. Change according to Certain Laws.—We have shown continuously progressive change in organic forms during the whole geologic history of the earth, similar in a general way to that observed in embryonic development. We wish now to show that the *laws of change* are similar in the two cases. What, then, are the laws of succession of organic forms in geologic times? I have been accustomed to formulate them thus: *a.* The law of differentiation; *b.* The law of progress of the whole; *c.* The law of cyclical movement.⁶ We will take up these and explain them successively, and then, afterward, show that they are also the laws of embryonic development, and therefore the laws of evolution.

a. Law of Differentiation.—It is a most significant fact, to which attention was first strongly directed by Louis Agassiz, that the earliest representatives of any group, whether class, order, or family, were not what we would now call typical representatives of that group; but, on the contrary, they were, in a wonderful degree, connecting links; that is, that along with their distinctive classic, ordinal, or family characters they possessed also other characters which connected them closely with other classes, orders, or families, now widely distinct, without connecting links or intermediate forms. For example: The earliest vertebrates were fishes, but not typical fishes. On the contrary, they were fishes so closely connected by many characters with amphibian reptiles, that we hardly know whether to call some of them reptilian fishes, or fish-like reptiles. From these, as from a common vertebrate stem, were afterward separated, by slow changes from generation to generation, in two directions, the typical fishes and the true reptiles. So, also, to take another example, the first birds were far different from typical birds as we now know them. They were, on contrary, birds so reptilian in character, that there is still some doubt whether bird-characters or reptilian characters predominate in the mixture,

and therefore whether they ought to be called reptilian birds or bird-like reptiles. From this common stem, the more specialized modern reptiles branched off in one direction and typical birds in another, and intermediate forms became extinct; until *now*, the two classes stand widely apart, without apparent genetic connection. This subject will be more fully treated hereafter, and other examples given. These two will be sufficient now to make the idea clear.

Such early forms combining the characters of two or more groups, now widely separated, were called by Agassiz *connecting* types, *combining* types, *synthetic* types, and sometimes *prophetic* types; by Dana, *comprehensive* types; and by Huxley, *generalized* types. They are most usually known now as *generalized* types, and their widely-separated outcomes *specialized* types. Thus, in general, we may say that the widely-separated groups of the present day, when traced back in geological times, approach one another more and more until they finally unite to form common stems, and these in their turn unite to form a common trunk. From such a common trunk, by successive branching and rebranching, each branch taking a different direction, and all growing wider and wider apart (differentiation), have been gradually generated all the diversified forms which we see at the present day. The last leafy ramifications—flower-bearing and fruit-bearing—of this tree of life, are the fauna and flora of the present epoch. The law might be called a law of ramification, of specialization of the parts, and diversification of the whole.

13

b. Law of Progress of the Whole.—Many imagine that progress is the one law of evolution; in fact, that evolution and progress are coextensive and convertible terms. They imagine that in evolution the movement must be upward and onward in all parts; that degeneration is the opposite of evolution. This is far from the truth. There is, doubtless, in evolution, progress to higher and higher planes; but not along every line, nor in every part; for this would be contrary to the law of differentiation. It is only progress of the whole organic kingdom in its entirety. We can best make this clear by an illustration. A growing tree branches and again branches *in all directions*, some branches going upward some sidewise, and some downward—anywhere, everywhere, for light and air; but the whole tree grows ever taller in its higher branches, larger in the circumference of its outstretching arms, and more diversified in structure. Even so the tree of life, by the law of differentiation, branches and rebranches continually in all directions—some branches going upward to higher planes (progress), some pushing horizontally; neither rising nor sinking, but only going farther from the generalized origin (specialization); some going downward (degeneration), anywhere, everywhere, for an unoccupied place in the economy of Nature, but the whole tree grows ever higher in its highest parts, grander in its proportions, and more complexly diversified in its structure.

14

It may be well to pause here a moment to show how this mistaken identification of evolution with progress alone, without modification by the more fundamental laws of differentiation, has given rise to misconceptions in the popular and even in the scientific mind. The biologist is continually met with the question, “Do you mean to say that any one of the invertebrates, such, for instance, as a spider, may eventually, in the course of successive generations, become a vertebrate, or that a dog or a monkey is on the highway to become a man?” By no means. There is but one straight and narrow way to the highest in evolution as in all else, and few there be that have found it—in fact, probably two or three only at every step. The animals mentioned above have diverged from that way. In their ancestral history, they have missed the golden opportunity, if they ever had it. It is easy to go on in the way they have chosen, but impossible to get back on the ascending trunk-line. To compare again with the growing tree, only one straight trunk-line leads upward to the terminal bud. A branch once separated must grow its own way, if it grow at all.

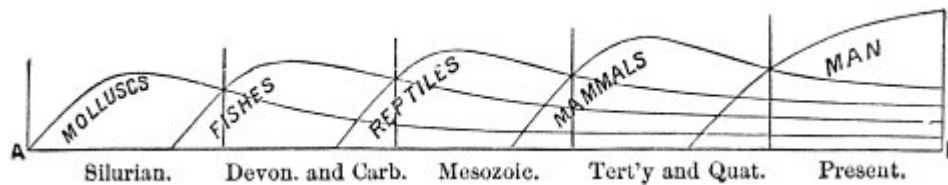
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Of the same nature is the mistake of some extreme evolutionists, such as Dr. Bastian and Professor Haeckel, and of nearly all anti-evolutionists, viz., that of imagining that the truth of evolution and that of spontaneous generation must stand or fall together. On the contrary, *if* life did *once* arise spontaneously from any lower forces, physical or chemical, by natural process, *the conditions necessary for so extraordinary a change could hardly be expected to occur but once in the history of the earth*. They are, therefore, *now*, not only unreproducible, but unimaginable. Such golden opportunities do not recur. Evolution goes only onward. Therefore, the impossibility of the derivation of life from non-life *now*, is no more an argument against such a derivation *once*, than is the

hopelessness of a worm ever becoming a vertebrate *now*, an argument against the derivative origin of vertebrates. Doubtless if life were now extinguished from the face of the earth, it could not again be rekindled by any natural process known to us; but the same is probably true of every step of evolution. If any class—for example, mammals—were now destroyed, it could not be re-formed from any other class now living. It would be necessary to go back to the time and conditions of the separation of this class from the reptilian stem. Therefore, the falseness of the doctrine of abiogenesis,⁷ so far from being any argument against evolution, is exactly what a true conception of evolution and knowledge of its laws would lead us to expect.

c. Law of Cyclical Movement.—The movement of evolution has ever been onward and upward, it is true, but not at uniform rate in the whole, and especially in the parts. On the contrary, it has plainly moved in successive cycles. The tide of evolution rose ever higher and higher, without ebb, but it nevertheless came in successive waves, each higher than the preceding and overborne by the succeeding. These successive cycles are the dynasties or reigns of Agassiz, and ages of Dana; the reign of mollusks, the reign of fishes, of reptiles, of mammals, and finally of *man*. During the early Palæozoic times (Cambrian and Silurian) there were no vertebrates.⁸ But never in the history of the earth were mollusks of greater size, number, and variety of form than then. They were truly the rulers of these early seas. In the absence of competition of still higher animals, they had things all their own way, and therefore grew into a great monopoly of power. In the later Palæozoic (Devonian) fishes were introduced. They increased rapidly in size, number, and variety; and being of higher organization they quickly usurped the empire of the seas, while the mollusca dwindled in size and importance, and sought safety in a less conspicuous position. In the Mesozoic times, reptiles, introduced a little earlier,⁹ finding congenial conditions and an unoccupied place above, rapidly increased in number, variety, and size, until sea and land seem to have swarmed with them. Never before or since have reptiles existed in such numbers, in such variety of form, or assumed such huge proportions; nor have they ever since been so highly organized as then. They quickly became rulers in every realm of Nature—rulers of the sea, swimming reptiles; rulers of the land, walking reptiles; and rulers of the air, flying reptiles. In the unequal contest, fishes therefore sought safety in subordination. Meanwhile mammals were introduced in the Mesozoic, but small in size, low in type (marsupials), and by no means able to contest the empire with the great reptiles. But in the Cenozoic (Tertiary) the conditions apparently becoming favorable for their development, they rapidly increased in number, size, variety, and grade of organization, and quickly overpowered the great reptiles, which almost immediately sank into the subordinate position in which we now find them, and thus found comparative safety. Finally, in the Quaternary, appeared man, contending doubtfully for a while, with the great mammals, but soon (in Psychozoic) acquiring mastery through superior intelligence. The huge and dangerous mammals were destroyed and are still being destroyed; the useful animals and plants were preserved and made subservient to his wants; and all things on the face of the earth are being readjusted to the requirements of his rule. In all cases it will be observed that the rulers were such because, by reason of strength, organization, and intelligence, they were fittest to rule. There is always room at the top. To illustrate again by a growing tree: This successive culmination of higher and higher classes may be compared to the flowering and fruiting of successively higher and higher branches. Each uppermost branch, under the genial heat and light of direct sunshine, received in abundance by reason of position, grew rapidly, flowered, and fruited; but quickly dwindled when overshadowed by still higher branches, which, in their turn, monopolized for a time the precious sunshine.

But observe, furthermore: when each ruling class declined in importance, it did not perish, but continued in a subordinate position. Thus, the whole organic kingdom became not only higher and higher in its highest forms, but also more and more complex in its structure and in the interaction of its correlated parts. The whole process and its result is roughly represented in the accompanying diagram, [Fig. 1](#), in which A B represents the course of geological time and the curve, the rise, culmination, and decline of successive dominant classes.



MOLLUSCS—Silurian.
FISHES—Devon. and Carb.
REEPTILES—Mesozoic.
MAMMALS—Tert'y and Quat.
MAN—Present.

FIG. 1.

THE ABOVE THREE LAWS ARE LAWS OF EVOLUTION.

These three laws we have shown are distinctly recognizable in the succession of organic forms in the geological history of the earth. They are, therefore, undoubtedly the *general laws of succession*. Are they also laws of evolution? Are they also discoverable in embryonic development, the type of evolution? They are, as we now proceed to show:

Differentiation.—In reproduction the new individual appears: 1. As a *germ-cell*—a single microscopic living cell. 2. Then, by growth and multiplication of cells, it becomes an *egg*. This may be characterized as an aggregate of *similar* cells, and therefore is not yet differentiated into tissues and organs. In other words, it is not yet visibly organized; for organization may be defined as the possession of different parts, performing different functions, and all co-operating for one given end, viz., the life and well-being of the organism. 3. Then commences the really characteristic process of development, viz., *differentiation* or diversification. The cells are at first all alike in form and function, for all are globular in form, and each performs all the functions necessary for life. From this common point now commences development in *different directions*, which may be compared to a branching and rebranching, with more and more complex results, according as the animal is higher in the scale of organization and advances toward a state of maturity. First, the cell-aggregate (*egg*) separates into three distinct layers of cells, called *ecto-blast*, *endo-blast*, and *meso-blast*. These by further differentiation form the three fundamental groups of organs and functions, viz., the *nervous system*, the *nutritive system*, and the *blood system*: the first presiding over the exchange of *force* or influence, by action and reaction with the environment, and between the different parts of the organism; the second presiding over the exchange of *matter* with the environment, by absorption and elimination; the third presiding over exchanges of matter between different parts of the organism. The first system of functions and organs may be compared to a system of telegraphy, foreign and domestic; the second to foreign commerce; the third to an internal carrying-trade. Following out any one of these groups in higher animals, say the nervous system, it quickly differentiates again into two sub-systems, viz., *cerebro-spinal* and *ganglionic*, each having its own distinctive functions, which we can not stop to explain. Then the *cerebro-spinal* again differentiates into voluntary and reflex systems. All of these have meanwhile separated into sensory and motor centers and fibers. Then, taking only the sensory fibers, these again are differentiated into five special senses, each having a wholly different function. Then, finally, taking any one of these, say the *sense of touch* or feeling, this again is differentiated into many kinds of fibers, each responding to a different impression, some to heat, others to cold, still others to pressure, etc. We have taken the nervous system; but the same differentiation and redifferentiation takes place in all other systems, and is carried to higher and higher points according to the position in the scale of the animal which is to be formed.

Or, to vary the mode of presentation a little, the cells of the original aggregate, commencing all alike, immediately begin to take on different forms, in order to perform different functions. Some cells take on a certain form and aggregate themselves to form a peculiar tissue which we call muscle, and

which does nothing else, can do nothing else, than contract under stimulus. Another group of cells take on another peculiar form and aggregate themselves to form another and very different tissue, viz., nervous tissue, which does nothing and can do nothing but carry influence back and forth between the great external world and the little world of consciousness within. Still another group of cells take still another form and aggregate to form still another tissue, viz., the *epithelial*, whose only function is to absorb nutritive and eliminate waste matters. Thus, by differentiation of form and limitation of function, or division of labor, the different parts of the organism are bound more and more closely together by mutual dependence, and the whole becomes more and more distinctly individuated, and separation of parts becomes more and more a mutilation, and finally becomes impossible without death. This process, as already said, reaches its highest point only in the later stages of development of the highest animals. 22

Progress.—The *law of progress* is, of course, admitted to be a law of ontogeny; but observe here, also, it is true only of the whole and not necessarily of all the parts, *except from the point of view of the whole*. Thus, for example, starting all from a common form or generalized type, some cells *advance* to the dignity of brain-cells, whose function is somehow connected with the generation or at least the manifestation of thought, will, and emotion; other cells *descend* to the position of kidney-cells, whose sole function is the excretion of urine. But here, also, the highest cells are successively higher, and the whole aggregate is successively nobler and more complex. It is again a branching and rebranching, in every direction, some going upward, some downward, some horizontally, anywhere, everywhere, to increase the complexity of relations internal and external, and therefore to elevate the plane of the whole.

Cyclical Movement.—Lastly, the law of cyclical movement is also a law of ontogeny and therefore of evolution. This law, however, is less fundamental than the other two, and is, therefore, less conspicuous in the ontogenic than in the phylogenic series. It is conspicuous only in the later stages of ontogeny, and in other higher kinds of evolution, such as social evolution. For example, in the ontogenic development of the body and mind from childhood to manhood we have plainly successive culminations and declines of higher and higher functions. In bodily development we have culminating first the *nutritive* functions, then the *reproductive* and *muscular*, and last the *cerebral*. In mental development we have culmination first of the receptive and retentive faculties in childhood, then of imaginative and æsthetic faculties in youth and young manhood; then of the reflective and elaborative faculties—the faculties of productive work in mature manhood; and, finally, the moral and religious sentiments in old age. The first gathers and stores materials; the second vivifies and makes them plastic building materials; the third uses them in actual constructive work—in building the temple of science and philosophy; and the fourth dedicates that temple only to noblest purposes. 23

Observe here, also, that when each group of faculties culminates and declines, it does not perish, but only becomes subordinate to the next higher dominant group, and the whole psychical organism becomes not only higher and higher in its highest parts, but also more and more complex in its structure and in the interaction of its correlated parts.

Observe, again, the necessity laid upon us by this law—the necessity of continued evolution to the end. Childhood, beautiful childhood, can not remain—it must quickly pass. If, with the decline of its characteristic faculties, the next higher group characteristic of youth do not increase and become dominant, then the glory of life is already past and deterioration begins. Have we not all seen sad examples of this? Youth, glorious youth, must also pass. If the next higher group of reflective and elaborative faculties do not arise and dominate, then progressive deterioration of character commences here—thenceforward the whole nature becomes coarse, as we so often see in young men, or else shrivels and withers, as we so often see in young women. Finally, manhood, strong and self-relying manhood, must also pass. If the moral and religious sentiments have not been slowly growing and gathering strength all along, and do not now assert their dominance over the whole man, then commences the final and saddest decline of all, and old age becomes the pitiable thing we so often see it. But, if the evolution have been normal throughout; if the highest moral and religious nature have been gathering strength through all, and now dominates all, then the psychic evolution rises to the end—then the course of life is like a wave rising and cresting only at the moment of its dissolution, or, 24

like the course of the sun, if not brightest at least most glorious in its setting. And thus—may we not hope?—the glories of the close of a well-spent life become the pledge and harbinger of an eternal tomorrow?

We have thus far illustrated the three laws of succession of organic forms by ontogeny, because this is the type of evolution; but they may be illustrated also by other forms of evolution. Next to the development of the individual, undoubtedly the *progress of society* furnishes the best illustration of these laws. 25

Commencing with a condition in which each individual performs all necessary social functions, but very imperfectly; in which each individual is his own shoemaker and tailor, and house-builder and farmer, and therefore all persons are socially alike; as society advances, the constituent members begin to diverge, some taking on one social function and some another, until in the highest stages of social organization this diversification or division and subdivision of labor reaches its highest point, and each member of the aggregate can do perfectly but one thing. Thus, the social organism becomes more and more strongly bound together by mutual dependence, and separation becomes mutilation. I do not mean to say that this extreme is desirable, but only that an approach to this is a natural law of social development. *Is not this the law of differentiation?*

So also *progress* is here, as in other forms of evolution—a *progress of the whole*, but not necessarily of every part. Some members of the social aggregate advance *upward* to the dignity of statesmen, philosophers, and poets; some advance *downward* to the position of scavengers and sewer-cleansers.¹⁰ But the highest members are progressively higher, and the whole aggregate is progressively grander and more complex in structure and functions. 26

So, again, the *law of cyclical movement* is equally conspicuous here. Society everywhere advances, not uniformly, but by successive waves, each higher than the last; each urged by a new and higher social force, and embodying a new and higher phase of civilization. Again: as each phase declines, its characteristic social force is not lost, but becomes incorporated into the next higher phase as a subordinate principle, and thus the social organism as a whole becomes not only higher and higher, but also more and more complex in the mutual relations of its interacting social forces.

Let us not be misunderstood, however. There is undoubtedly in social evolution something more and higher than we have described, but which does not concern us here, except to guard against misconstruction. There is in society a *voluntary progress* wholly different from the evolution we have been describing. In *true* or material evolution natural law works for the betterment of the whole utterly regardless of the elevation of the individual, and the individual contributes to the advance of the whole quite unconsciously while striving only for his own betterment. This unconscious evolution by natural law inherited from the animal kingdom is conspicuous enough in society, especially in its early stages, but we would make a great mistake if we imagined, as some do, that this is all. Besides the unconscious evolution by natural laws, *inherited from below*, there is a higher evolution, *inherited from above*, indissolubly connected with man's spiritual nature—a conscious, voluntary striving of the best members of the social aggregate for the betterment of the whole—a conscious, voluntary striving both of the individual and of society toward a recognized *ideal*. In the one kind of evolution the fittest are those most in harmony with the environment, and which therefore always survive; in the other, the fittest are those most in harmony with the ideal, and which often do not survive. The laws of this free voluntary progress are little understood. They are of supreme importance, but do not specially concern us here. We will speak of it again in another chapter. 27

The three laws above mentioned might be illustrated equally well by all other forms of evolution. We have selected only those which are most familiar. They may, therefore, be truly called the laws of evolution. We have shown that they are the laws of succession of organic forms.

III. Change by Means of Resident Forces.—Thus far in our argument I suppose that most well-informed men will raise no objection. It will be admitted, I think, even by those most bitterly opposed to the theory of evolution, that there has been throughout the whole geological history of the earth an onward movement of the organic kingdom to higher and higher levels. It will be admitted, also, that there is a grand and most significant resemblance between the course of development of the organic

kingdom and the course of embryonic development—between the laws of succession of organic forms and the laws of ontogenic evolution. But there is another essential element in ontogenic evolution. It is that the *forces* or causes of evolution are *natural*; that they reside in the thing developing and in the reacting environment. This we know is true of embryonic development; is it true also of the geologic succession of organic forms? It is true of ontogeny; is it true also of phylogeny? If not, then only by a metaphor can we call the process of change in the organic kingdom throughout geological history an evolution. This is the point of discussion, and not only of discussion, but, alas! of heated and even angry dispute. The field of discussion is thus narrowed to this third point only. 28

Before stating the two opposite views of the cause of evolution, it is necessary to remind the reader that when the evolutionist speaks of the forces that determine progressive changes in organic forms as *resident* or *inherent*, all that he means, or ought to mean, is that they are resident in the same sense as all natural forces are resident; in the same sense that the vital forces of the embryo are resident in the embryo, or that the forces of the development of the solar system according to the nebular or any other cosmogonic hypotheses are resident in that system. In other words, they mean only that they are *natural*, not supernatural. This does not, of course, touch that deeper, that deepest of all questions, viz., the essential *nature and origin of natural forces*; how far they are independent and self-existent, and how far they are only modes of divine energy. This is a question of philosophy, not of science. This question is briefly discussed in another place ([Part III, Chap. III](#)); it does not immediately concern us here. 29

The Two Views briefly Contrasted.—As already stated, all will admit a grand resemblance between the stages of embryonic development and those of the development of the organic kingdom. This was first brought out clearly by Louis Agassiz, and is, in fact, the greatest result of his life-work. All admit, also, that the embryonic development is a natural process. Is the development of the organic kingdom also a natural process? All biologists of the present day contend that it is; all the old-school naturalists, with Agassiz at their head, and all anti-evolutionists of every school, contend that it is not. We take Agassiz as the type of this school, because he has most fully elaborated and most distinctly formulated this view. As formulated by him, it has stood in the minds of many as an alternative and substitute for evolution.

According to the evolutionists, all organic forms, whether species, genera, families, orders, classes, etc., are variable, and, if external conditions favor, these variations accumulate in one direction and gradually produce new forms, the intermediate links being usually destroyed or dying out. According to Agassiz, the higher groups, such as genera, families, orders, etc., are indeed variable by the introduction of new species, but species are the ultimate elements of classification, and, like the ultimate elements of chemistry, are unchangeable; and, therefore, the speculations of the evolutionist concerning the transmutation of species are as vain as were the speculations of the alchemists concerning the transmutation of metals—that the origin of man, for example, from any lower species is as impossible as the origin of gold from any baser metal. Both sides admit frequent change of species during geological history, but one regards the change as a change by gradual *transmutation* of one species *into* another through successive generations and by *natural* process, the other as change by *substitution* of one species *for* another by direct supernatural *creative act*. Both admit the gradual development of the organic kingdom as a whole through stages similar to those of embryonic development; but the one regards the whole process as natural, and therefore strictly comparable to embryonic development, the other as requiring frequent special interference of creative energy, and therefore comparable rather to the development of a building under the hand and according to the preconceived plan of an architect—a plan, in this case, conceived in eternity and carried out consistently through infinite time. It is seen that the essential point of difference is this: The one asserts the variability of species (if conditions favor, and time enough is given) without limit; the other asserts the permanency of specific forms, or their variability only within narrow limits. The one asserts the origin of species by “*descent with modifications*”; the other, the origin of species by “*special act of creation*.” The one asserts the law of continuity (i. e., that each stage is the natural outcome of the immediately preceding stage) in this, as in every other department of Nature; the other asserts that the law of continuity (i. e., of cause and effect) does not hold in this department; that the links of the chain of changes are discontinuous, the connection between them being intellectual, not physical. 30

31

So much for sharp contrasting characterization of the two views, necessary for clear understanding of much that follows. We will have to give them more fully hereafter when we take up the evidences of evolution in [Part II](#).

CHAPTER II.

THE RELATION OF LOUIS AGASSIZ TO THE THEORY OF EVOLUTION.

In order to clear up the conception of evolution, it is necessary to give a brief history of the idea, and especially to explain the relation of Louis Agassiz to that theory. This is the more necessary, because there is a deep and wide-spread misunderstanding on this subject, and thus scant justice has been done our great naturalist, especially by the English and Germans; and also because this relation is an admirable illustration of an important principle in scientific philosophy.

Like all great ideas, we find the first germs of this in Greek philosophy, in the cosmic speculations of Thales and Pythagoras. Next (about 100 B. C.) we find it more clearly expressed by the Roman thinker, Lucretius, in his great philosophic poem entitled “*De Rerum Natura*.” After a dormancy of nearly eighteen centuries it next emerges with still more clearness in the theological speculations of Swedenborg and the philosophical speculations of Kant. All these we pass over with bare mention, because these thinkers approached the subject from the philosophic rather than the scientific side—in the metaphysical rather than the scientific spirit. 33

The first serious attempt at scientific presentation of the subject was by the celebrated naturalist, Lamarck, in a work entitled “*Philosophie Zoologique*,” published in 1809. It is not necessary, in this rapid sketch, to give a full account of Lamarck’s views. Suffice it to say that the essential idea of evolution, viz., the indefinite variability and the derivative origin of species, was insisted on with great learning and skill, and illustrated by many examples. With Lamarck, the factors of evolution or causes of change of organic forms were—1. Modification of organs in function and therefore in structure, by a changing environment—external factor; and, 2. Modification of organs by *use* and *disuse*—internal factor. In both cases the modifications are inherited and increased from generation to generation, without limit. This second factor seems to have taken, in the mind of Lamarck, the somewhat vague and transcendental form of aspiration or upward striving of the animal toward higher conditions. These are acknowledged to-day as true factors of evolution, but the distinctively Darwinian factor, viz., “divergent variation and natural selection,” was not then thought of. The publication of Lamarck’s views produced a powerful impression, but only for a little while. Pierced by the shafts of ridicule shot by nimble wits of Paris, and crushed beneath the heavy weight of the authority of Cuvier, the greatest naturalist and comparative anatomist of that or perhaps of any time, it fell almost still-born. I believe it was best that it should thus perish. Its birth was premature; it was not fit to live. The world was not yet prepared for a true scientific theory. Nevertheless, the work was not without its effect upon some of the most advanced thinkers of that time; upon Saint-Hilaire and Comte in France, and upon Goethe and Oken in Germany. It was good seed sown and destined to spring up and bear fruit in suitable environment; but not yet. 34

The next attempt worthy of attention in this rapid sketch is that of Robert Chambers, in a little volume entitled “*Vestiges of a Natural History of Creation*,” published in 1844. It was essentially a reproduction of Lamarck’s views in a more popular form. It was not a truly scientific work nor written by a scientific man. It was rather an appeal from the too technical court of science to the supposed wider and more unprejudiced court of popular intelligence. It was therefore far more eloquent than accurate; far more specious than profound. It was, indeed, full of false facts and inconsequent reasonings. Nevertheless, it produced a very strong impression on the thinking, popular mind. But *it* also quickly fell, pierced by keen shafts of ridicule, and crushed beneath the heavy weight of the authority of all the most prominent naturalists of that time, with Agassiz at their head. The question for the time seemed closed. I believe, again, it was best so, for the time was not yet fully ripe.

I know full well that many think with Haeckel that biology was kept back half a century by the baneful authority of Cuvier and Agassiz; but I can not think so. The hypothesis was contrary to the facts of science *as then known and understood*. It was conceived in the spirit of baseless speculation, rather than of cautious induction; of skillful elaboration rather than of earnest truth-seeking. Its general acceptance would have debauched the true spirit of science. I repeat it: the time was not yet ripe for a scientific theory. The ground must first be cleared and a solid foundation built; an insuperable *obstacle* to hearty rational acceptance must first be removed, and an inductive *basis* must be laid.

The Obstacle removed.—The obstacle in the way of the acceptance of the derivative origin of species was the then prevalent *notion concerning the nature of life*. We must briefly sketch the change which has taken place in the last forty years in our ideas on this subject.

Until about forty years ago, the different forces of Nature, such as gravity, electricity, magnetism, light, heat, chemical affinity, etc., were supposed to be entirely distinct. The realm of Nature was divided up into a number of distinct and independent principalities, each subject to its own sovereign force and ruled by its own petty laws. About that time it began to be evident, and is now universally acknowledged, that all these forces are but different *forms* of one, universal, omnipresent energy, and are transmutable unto one another back and forth without loss. This is the doctrine of correlation of forces and conservation of energy, one of the grandest ideas of modern times. But *one* force seemed still to be an exception. Life-force was still believed to be a peculiar, mysterious principle or entity, standing above other forces and subordinating them; not correlated with, not transmutable unto, nor derivable from, other and lower forces, and therefore in some sense supernatural. Now, if this be true of living *forces*, it is perfectly natural, yea, almost necessary, to believe that living *forms* are wholly different from other forms in their origin. New forms of dead matter may be derived, but new living forms are *undervived*. Other new forms come by natural process, new organic forms by supernatural process. The conclusion was almost unavoidable. But soon vital force also yielded to the general law of correlation of natural forces. Vital forces are also transmutable into and derivable from physical and chemical forces. Sun-force, falling on the green leaves of plants, is absorbed and converted into vital force, disappears as *light* to reappear as *life*. The amount of life-force generated is measured by the amount of light extinguished. The same is true of animal life. As in the steam-engine the locomotive energy is derived from the fuel consumed and measured by its amount, so in the animal body, the animal heat and animal force are derived from and measured by the food and tissue consumed by combustion. Thus, vital force may be regarded as so much force withdrawn from the general fund of chemical and physical forces, to be again refunded without loss at death. This obstacle is, therefore, now removed. If vital force falls in the same category as other natural forces, there is no reason why living forms should not fall into the same category in this regard as other natural forms. If new forms of dead matter are derived from old forms by modification, according to *physical* laws, there is no reason why new living forms should not also be derived from old forms by modification according to *physiological* laws. Thus, at last, the obstacle was removed—the ground was cleared.

The Basis laid.—But Science is not content with removal of *a priori* objections. She must also have positive proofs. The ground must not only be cleared, but a true inductive basis of facts, and especially of laws and methods, must be laid. *This was the life-work of Agassiz*. Yes, as strange as it may seem to some, it is nevertheless true that the whole inductive basis, upon which was afterward built the modern theory of evolution, was laid by Agassiz, although he himself persistently refused to build upon it any really scientific superstructure. It is plain, then, that all attempts at building previous to Agassiz's work must, of necessity, have resulted in an unsubstantial structure—an edifice built on sand, which could not and ought not to stand. I must stop here in order to explain somewhat fully this important point, and thus to give due credit to the work of Agassiz.

The title of any scientist to greatness must be determined, not so much by the multitude of new facts he has discovered as by the new laws he has established, and especially by the new methods he has inaugurated or perfected. Now, I think it can be shown that to Agassiz, more than to any other man, is due the credit of having *established the laws of succession of living forms* in the geological history of the earth—laws upon which must rest any true theory of evolution. Also, that to him, more than to any other man, is due the credit of having *perfected the method* (method of comparison) by the

use of which alone biological science has advanced so rapidly in modern times. This is high praise. I wish to justify it. I begin with the method.

Scientific methods bear the same relation to *intellectual progress* that tools, instruments, machines, mechanical contrivances of all sorts, bear to *material progress*. They are intellectual *contrivances*—indirect ways of accomplishing results far too hard for bare-handed, unaided intellectual strength. As the civilized man has little or no advantage over the savage in bare-handed strength of muscle, and the enormous superiority of the latter in accomplishing material results is due wholly to the use of mechanical contrivances or machines; even so, in the higher sphere of intellect, the scientist makes no pretension to the possession of greater unaided intellectual strength than belongs to the uncultured man, or even perhaps to the savage. The amazing intellectual results achieved by science are due wholly to the use of intellectual contrivances or scientific methods. As in the lower sphere of material progress the greatest benefactors of the race are the inventors or perfecters of new mechanical contrivances or *machines*, so also in the higher sphere of intellectual progress the greatest benefactors of the race are the inventors or perfecters of new intellectual contrivances or *methods of research*.

39

To illustrate the power of methods, and the necessity of their use, take the case of the *method of notation*, so characteristic of mathematics, and take it even in its simplest and most familiar form: Nine numeral figures, having each a value of its own, and another dependent upon its position; a few letters, *a* and *b*, and *x* and *y*, connected by symbols, + and-and =: that is all. And yet, by the use of this simple contrivance, the dullest school-boy accomplishes intellectual results which would defy the utmost efforts of the unaided strength of the greatest genius. And this is only the simplest tool-form of this method. Think of the results accomplished by the use of the more complex machinery of the higher mathematics!

Take next the method of experiment so characteristic of physics and chemistry. The phenomena of the external world are far too complex and far too much affected by disturbing forces and modifying conditions to be understood at once by bare, unaided intellectual insight. They must first be simplified. The physicist, therefore, contrives artificial phenomena under ideal conditions. He removes one complicating condition after another, one disturbing cause and then another, watching meanwhile the result, until finally the necessary condition and the true cause are discovered. On this method rests the whole fabric of the physical and chemical sciences.

But when we rise still higher, viz., into the plane of life, the phenomena of Nature become still more complex and difficult to understand directly; and yet just here, where we are the most powerless without some method, our method of experiment almost wholly *fails us*. The phenomena of life are not only far more complex than those of dead matter, but the conditions of life are so nicely adjusted, the equilibrium of forces so delicately balanced, that, when we attempt to introduce our clumsy hands in the way of experiment, we are in danger of overthrowing the equilibrium, of destroying the conditions of the experiment, viz., life; and then the whole problem falls immediately into the domain of chemistry. What shall we do? In this dilemma we find that Nature herself has already prepared for us, ready to hand, an elaborate series of simplified conditions equivalent to experiments. The phenomena of life are, indeed, far too complex to be at once understood—the problem of life too hard to be solved—in the higher animals; but, as we go down the animal scale, complicating conditions are removed one by one, the phenomena of life become simpler and simpler, until in the lowest microscopic cell or spherule of living protoplasm we finally reach the simplest possible expression of life. The equation of life is reduced to its simplest terms, and now, if ever, we begin to understand the true value of the unknown quantity. This is the natural history series, or *Taxonomic* series, already spoken of on [page 10](#). Again, Nature has prepared, and is now preparing daily before our eyes, another series of gradually simplified conditions. Commencing with the mature condition of one of the higher animals—for example, man—and going backward along the line of individual history through the stages of infant embryo, egg and germ, we find again the phenomena of life becoming simpler and simpler, until we again reach the simplest conceivable condition in the single microscopic cell or spherule of living protoplasm. This, as already explained, is the embryonic or *Ontogenic* series. Again, that there be no excuse for man's ignorance of the laws of life, Nature has prepared still another series; and this the

40

41

grandest of all, for it is the cause of both the others. Commencing with the plants and animals of the present epoch, and going back along the track of geological times, through Cenozoic, Mesozoic, Palæozoic, Eozoic, to the very dawn of life—the first syllable of recorded time—and we find again a series of organic forms growing simpler and simpler, until, if we could find the very first, we would undoubtedly again reach the simplest condition in the lowest conceivable forms of life. This, as we have already seen, is the geologic or evolution, or *Phylogenic* series. We have already explained these three series, only in this connection it suits our purpose to take the terms backward.

Now, it is by *comparison* of the terms of each of these series going up and down, and watching the first appearance, the growth, and the perfecting of tissues, organs, functions, and by the comparison of the three series with one another term by term—I say it is wholly by comparison of this kind that biology has in recent times become a true inductive science. This is the “*method of comparison*.” It is the great method of research in all those departments which can not be readily managed by the method of experiment. It has already regenerated biology, and is now applied with like success in sociology under the name of *historic method*. Yes; anatomy became scientific only through comparative anatomy, physiology through comparative physiology, and embryology through comparative embryology. May we not add, sociology will become truly scientific only through comparative sociology, and psychology through comparative psychology?

42

Now, while it is true that this method, like all other methods, has been used, from the earliest dawn of thought, in a loose and imperfect way, yet it is only in very recent times that it has been organized, systematized, perfected, as a true scientific method, as a great instrument of research; and the prodigious recent advance of biology is due wholly to this cause. Now, among the great leaders of this modern movement, Agassiz undoubtedly stands in the very first rank. I must try to make this point plain, for it is by no means generally understood.

Cuvier is acknowledged to be the great founder of comparative anatomy. He it was that first perfected the method of comparison, but comparison only in one series—the *Taxonomic*. Von Baer and Agassiz added to this comparison in the ontogenic series also, and comparison of these two series with each other, and therefore the application of embryology to the classification of animals. If Von Baer was the first announcer, Agassiz was the first great practical worker by this method. Last and most important of all, in its relation to evolution, Agassiz added *comparison in the geologic or phylogenic series*. The one grand idea underlying Agassiz’s whole life-work was the essential identity of the three series, and therefore the light which they must shed on one another. The two guiding and animating principles of his scientific work were—1. That the embryonic development of one of the higher representatives of any group repeated in a general way the terms of the Taxonomic series in the same group, and therefore that embryology furnished the key to a true classification; and, 2. That the succession of forms and structure in geological times in any group is similar to the succession of forms and structure in the development of the individual in the same group, and thus that embryology furnishes also the key to geological succession. In other words, during his whole life, Agassiz insisted that the laws of embryonic development (ontogeny) are also the laws of geological succession (phylogeny). Surely this is the foundation, the only solid foundation, of a true theory of evolution. It is true that Agassiz, holding as he did the doctrine of permanency of specific types, and therefore rejecting the doctrine of the derivative origin of species, did not admit the causal or natural relation of phylogenic succession to embryonic succession and taxonomic order as we now believe it—it is true that for him the relation between the three series was an intellectual not a physical one—consisted in the preordained plans of the Creator, and not in any genetic connection or inherited property; but evidently the first and greatest step was the discovery of the relation itself, however accounted for. The rest was sure to follow.

43

44

But more. Not only did Agassiz establish the essential identity of the geologic and embryonic succession, the general similarity of the two series, phylogenic and ontogenic, but he also announced and enforced all the formal laws of geologic succession (i. e., of evolution), as we now know them. These, as already stated and illustrated, are the law of differentiation, the law of progress of the whole, and the law of cyclical movement, although he did not formulate them in these words. No true inductive evidence of evolution was possible without the knowledge of these laws, and for this

knowledge we are mainly indebted to Agassiz. He well knew also that they were the laws of embryonic development and therefore of evolution; but he avoided the word evolution, as implying the derivative origin of species, and used instead the word *development*, though it is hard to see in what the words differ. Thus, it is evident that Agassiz laid the whole foundation of evolution, solid and broad, but refused to build any scientific structure on it; he refused to recognize the legitimate, the scientifically necessary outcome of his own work. Nevertheless, without his work a scientific theory of evolution would have been impossible. Without Agassiz (or his equivalent), there would have been no Darwin.

45

There is something to us supremely grand in this refusal of Agassiz to accept the theory of evolution. The opportunity to become the leader of modern thought, the foremost man of the century, was in his hands, and he refused, because his religious, or, perhaps better, his philosophic intuitions, forbade. To Agassiz, and, indeed, to all men of that time, to many, alas! even now, evolution is materialism. But materialism is Atheism. Will some one say, the genuine Truth-seeker follows where she seems to lead *whatever be the consequences*? Yes; whatever be the consequences to one's self, to one's opinions, prejudices, theories, philosophies, but not to *still more certain truth*. Now, to Agassiz, as to all genuine thinkers, the existence of God, like our own existence, is more certain than any scientific theory, than anything can possibly be made by proof. From his standpoint, therefore, he was right in rejecting evolution as conflicting with still more certain truth. The mistake which he made was in imagining that there was any such conflict at all. But this was the universal mistake of the age. A lesser man would have seen less clearly the higher truth and accepted the lower. A greater man would have risen above the age, and seen that there was no conflict, and so accepted both. All thinking men are coming to this conclusion now, but none had done so then.

Now, then, at last, the obstacle of supernaturalism in the realm of Nature having been removed by the establishment of the doctrine of correlation of natural forces, and the extension of this doctrine to embrace also life-force; and now also a broad and firm basis of carefully-observed facts and well-established laws of succession of organic forms having been laid by Agassiz, when again, for the third time, the doctrine of origin of species "by derivation with modifications" was brought forward by Darwin in a far more perfect form, with more abundant illustrative materials, and with a new and most potent factor of modification—viz., divergent variations and natural selection—it found the scientific world already fully prepared, and anxiously waiting. I say *anxiously* waiting—for the supposed supernatural origin of species had been the one exception to the otherwise universal law of cause and effect, or the law of continuity. It was therefore in open contradiction to the whole drift of scientific thought for five hundred years. Is it any wonder, then, that the derivative origin of species was welcomed with joy by the scientific world? For five hundred years, scientific thought, like a rising tide which knows no ebb, had tended thitherward with ever-increasing pressure, but kept back by the one supposed fact of the supernatural origin of species. Darwin lifted the gate, and the in-rushing tide flooded the whole domain of thought.

46

What, then, is the place of Agassiz in biological science? What is the relation of Agassiz to Darwin—of Agassizian development to Darwinian evolution? I answer, it is the relation of formal science to physical or causal science. Agassiz advanced biology to the *formal* stage; Darwin carried it forward, to some extent at least, to the *physical* stage. All true inductive sciences in their complete development pass through these two stages. Science in the one stage treats of the *laws* of phenomena; in the other, of the *causes* or explanation of these laws. The former must precede the latter, and form its foundation; the latter must follow the former, and constitute its completion. The change from the one to the other is always attended with prodigious impulse to science.

47

To illustrate: Until Kepler, astronomy was little more than an accumulation of disconnected facts concerning celestial motions—abundant materials, but no science; piles of brick and stone, but no building. Kepler reduced this chaos to beautiful order and musical harmony by the discovery of the three great laws which bear his name, and therefore he has been justly called the legislator of the heavens—the *lawgiver of space*. But, had he been asked the *cause* of these beautiful laws, he could only have answered, "The *first cause*—the direct will of the Deity." A good answer and a true, but not scientific; because it places the question beyond the domain of science, which deals only with second

or physical causes. But Newton comes forward and gives a *physical cause*. He shows that all these beautiful laws are the necessary result of gravitation; and thus astronomy becomes a physical science. So, until Agassiz, the facts of geological succession of organic forms were in a state of lawless confusion. Agassiz by establishing the three great laws of succession, which ought to bear his name, reduced this chaos to order and beauty; and, therefore, he might justly be called the legislator of geological history—the *lawgiver of time*. But, when asked the cause of these laws, he could only answer, and did indeed answer, “The plans of the Creator.” A noble answer and true, but not scientific. Darwin now comes forward and gives, partly at least, the cause of these laws. He shows that all these beautiful laws are explained by the doctrine of “origin of species by derivation with modifications”; that these laws are not ultimate, but derivative from more fundamental laws of life; and thus biology is advanced one step, at least, toward the causal stage. Newton and Darwin substituted second causes for first cause—natural for supernatural. They each in his own department broke the bonds of supernaturalism in the domain of Nature.

48

One more important reflection: There are two, and only two, fundamental conditions of material existence—*space* and *time*. There are, therefore, two, and only two, cosmoses—space-cosmos and time-cosmos. These have been redeemed from confusion and reduced to law and order and beauty—changed from chaos to cosmos—by science. For this result we are chiefly indebted, in the one case, to Kepler and Newton; in the other, to Agassiz and Darwin. The universal law, in the one cosmos, is the *law of gravitation*; in the other, the *law of evolution*. Traced by analysis to its deepest roots of philosophic truth, the one law may be called the divine mode of sustentation; the other, the divine process of creation.

49

Or again: we have all heard of the “music of the spheres”—a beautiful and significant name used by the old thinkers for the divine order of the universe—a music heard not by human ear, but only by the attentive human spirit. Harmonic relation apprehended by *reason* we call *Law*, and its embodiment Science; the same apprehended by the imagination and æsthetic sense, we call *Beauty*, and its embodiment *Art, music*. Now, in music there are two kinds of harmony, simultaneous and consecutive—chordal harmony and melody. These must be combined to produce the grandest effect. So in cosmic order, too, there are two kinds of harmonic relation—the *co-existent in space* and the *consecutive in time*. The law of gravitation expresses the universal harmonic inter-relation of *objects* co-existent in space, the law of evolution, the universal harmonic relation of *forms* successive in time. Of the divine spherical music, the one is the chordal harmony, the other the consecutive harmony or melody. Combined they form the divine chorus which “the morning stars sang together.”

51

PART II.

EVIDENCES OF THE TRUTH OF EVOLUTION.

CHAPTER I.

GENERAL EVIDENCES OF EVOLUTION AS A UNIVERSAL LAW.

Let us again remind the reader that evolution means, first of all, *continuity*. The law of evolution, although it doubtless means much more, means, first of all, a law of continuity, or *causal relation throughout Nature*. It means that, alike in every department of Nature, each state or condition grew *naturally* out of the immediately preceding. In a word, it means that, in the course of Nature, nothing appears suddenly and without natural cause, but, on the contrary, everything is the natural and usually the gradual outcome of a previous condition. This is *now* admitted by every one in regard to *nearly* everything: evolutionists apply it to the whole course of Nature. I said this is *now* admitted by every one in regard to *nearly* everything; but this has not always been so. The world has come to its present position on this subject only by a very gradual process. Let us then trace rapidly the history of the gradual change, for it will prepare us for much that follows.

There was a time (and that not many decades ago) when all things, the origin of which transcends our ordinary experience, were supposed to have originated suddenly and without natural process—to have been made at once, out of hand. There was a time when, for example, mountains were supposed to have been made at once, with all their diversified forms, of beetling cliffs and thundering waterfalls, or gentle slopes and smiling valleys, just as we now find them. But *now* we know that they have become so only by a very gradual process, and are still changing under our very eyes. In a word, they have been formed by a *process of evolution*. We know now the date of mountain-births; we trace their growth, maturity, decay, and death; and find even, as it were, the fossil bones of extinct mountains in the crumpled strata of their former places. There was a time when continents and seas, gulfs, bays, and rivers, were supposed to have originated at once, substantially as we now see them. *Now*, we know that they have been changing throughout all geological time, and are still changing. Not, however, change back and forth in any direction indifferently and without goal, but gradual change from less perfect to more perfect condition, with more and more complex inter-relations—i. e., by a *process of evolution*. We are able now, though still imperfectly, to trace some of the stages of this evolution. There was a time when rocks and soils were supposed to have been always rocks and soils; when soils were regarded as an original clothing made on purpose to hide the rocky nakedness of the new-born earth. God clothed the earth so, and there an end. *Now* we know that rocks rot down to soils; soils are carried down and deposited as sediments; and sediments re-consolidate as rocks—the same materials being worked over and over again, passing through all these stages many times in the history of the earth. In a word, there was a time when it was thought that the earth with substantially its present form, configuration, and climate, was made at once out of hand, as a fit habitation for man and animals. *Now* we know that it has been changing, preparing, becoming what it is by a slow process, through a lapse of time so vast that the mind sinks exhausted in the attempt to grasp it. It has become what it now is by a *process of evolution*. The same change of view has taken place concerning the origin of all the heavenly bodies. We may, therefore, confidently generalize—we may assert without fear of contradiction that *all inorganic forms*, without exception, have originated by a process of evolution.

The proof of all this we owe to geology—a science born of the present century. This science establishes the law of *universal continuity* of events, through infinite *time*, as astronomy does that of *universal inter-relation* of objects through infinite *space*. How great the change these two sciences have made in the realm of human thought! Until the birth of modern astronomy the intellectual *space-horizon* of the human mind was bounded substantially by the dimensions of our earth; sun, moon, and stars, being but inconsiderable bodies circulating at a little distance about the earth, and for our behoof. Astronomy was then but the geometry of the curious lines traced by these wandering fires on the

54

55

56

concave blackboard of heaven. With the first glance through a telescope the phases of Venus and the satellites of Jupiter, revealed clearly to the mind the existence of other worlds besides and like our own. In that moment the idea of *infinite space*, full of worlds like our own, was for the first time completely realized, and became thenceforward the heritage of man. In that moment the *intellectual horizon of man was infinitely extended*. So also until the birth of geology, about the beginning of the present century, the intellectual *time-horizon* of the human mind was bounded by six thousand years. The discovery about that time of vertebrate remains, all wholly different from those now inhabiting the earth, revealed the existence of other time-faunas, besides our own and the idea of infinite time, of which the life of humanity is but an epoch, was born in the mind of man; and again the intellectual horizon of man was infinitely extended. These two are the grandest ideas, and their introduction the grandest epochs, in the intellectual history of man. We have long ago accepted and readjusted our mental furniture to the requirements of the one, but the necessary readjustment to the other is not yet complete.

All inorganic forms, then, it is admitted, have come by evolution. But how is it with organic or living forms? Let us see.

Every one knows, because it is within the limits of ordinary experience, that every *individual* organism *now* originates and gradually becomes what we see it, by a natural process—that is, by evolution. If, then, there be any exception, it must be only the *first of each kind*. But what kind? There are many kinds of kinds; classes, orders, families, genera, species, varieties. Now, many of these kinds can be shown to have become what we see them by a gradual process similar, at least, to evolution. Take for example, classes. The class of fishes and the class of reptiles are *now* widely distinct and have little in common except a vertebrate structure; but, as already shown, [page 12](#), this extreme difference has not always existed. On the contrary, the earliest representatives of these two classes so merged into one another that each seemed either. From this common stock the two classes were gradually separated, each going its own way and becoming more and more widely distinct even to the present day. There can be no doubt, therefore, that *these two classes*, as we now know them, *have become* what they are by a gradual process. Again: In the whole realm of Nature there is not a class more distinctly separate from every other and without intermediate links than birds. But this has not always been so. They have gradually become so. The earliest birds were so reptilian in structure and appearance that if we could see them now we would be in doubt whether we should call them birds or reptiles. Birds have gradually separated themselves from the reptilian stem, becoming more and more bird-like from age to age, until now, at last, the two classes are wholly separated and the intermediate links destroyed. So far as external characters are concerned, birds may be said to have finally and wholly released themselves from entangling alliance with any other class.

Classes, then, it will be admitted, have undoubtedly become what we now know them by a very gradual process following laws identical (as we have already seen, [page 19](#)) with the laws of evolution. Shall we try orders? Of the class Mammalia there are two well-recognized and widely-distinct *orders*, viz., the Carnivores and the Herbivores. We all know how widely diverse these are in form, in structure, in habits, and in food. Has it always been so? Have these been made so at once? By no means. They have gradually become so. The earliest mammals were neither the one nor the other distinctively. They were *omnivores*, completely intermediate in food, habits, form, and structure. From this common stock the two orders have gradually separated, the carnivores becoming more and more adapted to one mode of life and the herbivores to another, by a process following the laws of evolution, as already explained. Shall we try *families* and *genera*? Marsh and Huxley have shown us how completely the horse family (*Equidæ*) and the horse-genus (*Equus*) illustrate the process of gradual becoming and the law of evolution. Under their guidance, we see that the earliest traceable ancestor of the horse family, before it was distinctively a horse family at all, had on the fore-foot five toes in the Lower Eocene, four toes in the Upper Eocene, and three toes in the Miocene; then we see the two side-toes shortening up more and more in the Pliocene and becoming rudimentary splints, leaving only one toe in the Quaternary and present epochs. Thus, the side-splints in the foot of the modern horse tell the story of its three-toed ancestry. Similar gradual changes are clearly traceable in size, shape, structure of limbs, of teeth, and of brain. In all respects the members of the horse family have become more and more horse-like in the course of time.

This subject will be taken up and more fully illustrated, under the head of special evidences, in a subsequent chapter. We here touch it only sufficiently to illustrate this universal law of gradual becoming.

We have taken only a few examples, but the same is undoubtedly true of all Taxonomic groups *above species*. Passing over these last for the moment, we take next *races* and *varieties*. These smaller groups are admitted by all to be formed by a natural process, because not only can we make them artificially, but all the intermediate links may be found in Nature. So we have only *species* remaining. Yes; species are imagined by the old-school naturalist and by the anti-evolutionist of to-day as the *ultimate elements* of Taxonomy. This, then, is the *last ditch* upon which the defense of supernaturalism in the realm of Nature is made. "Other groups," they say, "may have gradually become what they now are by the successive introduction of specific forms according to a preordained plan which is well expressed by the formal laws of evolution. But *species* are without transition forms. *They* come in suddenly, remain unchanged while they continue, and finally pass out suddenly, so far as specific characters are concerned. New species come in their places by direct act of creation—by *substitution*, not by transmutation." This, then, is the last intrenchment. Can we give any good evidence of gradual formation of species? I believe we can.

60

First, then, it is admitted that we can easily make varieties and races artificially. We will not *now* describe the process; we are all familiar with the results, viz., the varieties of domestic animals and of useful and ornamental plants; the extremely different breeds of horses, cattle, sheep, dogs, pigeons, etc.; of wheat, cabbages, turnips; of roses, dahlias, etc., etc. No one will doubt that the extreme varieties of any of these, say greyhound and pug, if wild, would be called distinct species, or even distinct genera. We do not call them so, for two reasons: first, because we see them made; and, second, because we find all intermediate links between them; and the usual definition of species is that they can not be made, and they have no intermediate links. Thus, then, the question is narrowed down to *wild species*. They say: "We take our stand on these" (surely a very narrow ground for so broad a philosophy). "We defy you to show gradual formation with intermediate links."

Now, in fact, by diligent search such intermediate links between well-recognized species have been found in some cases, especially in birds, on account of their great power of dispersal. Certain forms have long been known from widely-separated regions, and universally regarded as distinct species, as distinct as any. Then, by minute examinations of intermediate regions, a complete series of intermediate forms has been picked up. This has occurred not only in one case but in many cases, and not in birds only but in many other classes—examples increase with our increasing knowledge.¹¹ The only answer to such evidence is that *these are not true species*. Now, see the fallacy lurking here! They define species as ultimate elements of taxonomy, as distinct and without intermediate links, and then require us to find such intermediate links; and, finally, when with infinite pains some such links are found, they say: "Oh! I see; we were mistaken; they are only varieties!!" It is true that naturalists, when intermediate links are found, usually put all together as one species, but this they do purely for the sake of clearness of definition and description. It is freely admitted by the evolutionist that species are *now* usually distinct and without intermediate links, these having been destroyed in the struggle for life. This will be fully explained in another chapter. It is also freely admitted that although intermediate links must have existed at one time, their remains are rarely found. The reason of this will also be explained hereafter. Nevertheless, in some cases, as already seen, we do find them still existing. Now, we add that in some cases, where they no longer exist, we find them in the form of fossil remains. The most remarkable example of this is found in the gradual changes in the forms of *Planorbis* in the fresh-water deposits of Steinheim, as shown by the admirable researches of Hyatt.¹² We shall discuss these also more fully in another place. Now, if there be any such links at all, however rare, then every objection to the derivative origin of species is removed.

61

62

Perhaps it may be well to make bare mention of another kind of evidence, viz., the actual change of species under the eyes, by the action of change of environment. The different species of the genus *Artemia* (a low form of crustacean) live in brine-pools. By concentrating the brine of such a pool, one species (*A. salina*) has been observed to change in successive generations into another (*A. Muhlhausenii*), and the latter back again to the former by slow freshening.¹³ Again: The siredon and

the amblystoma have always, until recently, been regarded as not only distinct species, but distinct genera of amphibians. Siredon was supposed to be a permanent gill-breather, while amblystoma becomes by metamorphosis a pure air-breather. Now, however, it is known that the former may change into the latter. But the most curious part of the life-history of these animals, is that if water be abundant the siredon reproduces freely, and remains indefinitely a gill-breather; but if the water dries up it changes into the lung-breathing amblystoma. We do not give this as examples of change of species, for the change is in the individual life, and therefore in the nature of metamorphosis, but as evidence of the power of physical conditions in modifying the development of organic forms and therefore of the manner in which gill-breathers were probably transformed into air-breathers.

63

To sum up: 1. All *inorganic* forms, without exception, have become what we find them by a natural process—i. e., by evolution. 2. All *organic* or living forms within the *limits of observation*, i. e., every living thing, has become what we now see, by a gradual, natural process—i. e., by evolution. 3. All taxonomic groups, except species, have undoubtedly become what we now see them by a gradual process, following the laws of evolution, and therefore presumably by a natural process of evolution. 4. By artificial means, breeds, races, etc., very similar, at least in many respects, to species, are seen to arise by a gradual natural process—i. e., by evolution. 5. In some instances, at least, natural species are observed to pass into one another by intermediate links in such wise that we are forced to conclude that they have been formed by a natural process.

May we not, then, safely generalize, and make the law universal? Is not this a sufficient ground for confident induction? Even though some facts are still inexplicable, is that a sufficient reason for withholding assent to a theory which explains so much? In all induction we first establish a law provisionally from the observation of a comparatively few facts, and then extend it over a multitude of facts not included in the original induction. If it explains these also, the law is verified. The law of gravitation was first based on the observation of a few facts, and then verified by its explanation of nearly all the facts of celestial motion. There are some outstanding facts of celestial motion still unexplained, but we do not, therefore, doubt the law of gravitation. The same principle applied in biology ought to establish the law of evolution, for it also explains all the facts of biology as no other law can. But inductive evidence differs from other kinds of evidence in one respect, which, in fact, constitutes its strength to the scientific, but its weakness to the popular mind. It is a kind of circumstantial evidence, but its force does not consist in a few strong circumstances easily appreciated, such as strike the popular mind, and force conviction, but rather in a multitude of small circumstances, each by itself insignificant, but all together pointing to one conclusion and demanding one explanation. Such evidence is, indeed, overwhelming, but only to the mind that masters it. The evidence for the law of gravitation is literally the whole science of astronomy. So also the evidence for the law of evolution is the whole science of biology. Neither of these laws can be proved in a debating society, but only by a course of study. In the one case the law has been universally accepted—not, however, on evidence, for there are few indeed who appreciate the evidence, but on the authority of scientific unanimity. In the other case there has not yet been time enough for the already established unanimity to have its full effect.

64

65

Thus much, we believe, will be generally admitted as a very moderate claim. Evolution is certainly a legitimate induction from the facts of biology. But we are prepared to go much further. We are confident that evolution is *absolutely certain*. Not, indeed, evolution as a special theory—Lamarckian, Darwinian, Spencerian—for these are all more or less successful modes of explaining evolution; nor evolution as a school of thought, with its following of disciples—for in this sense it is still in the field of discussion—but evolution as a law of derivation of forms from previous forms; evolution as a law of continuity, as a universal law of becoming. In this sense it is not only certain, it is axiomatic. It is only necessary to conceive it clearly, to see that it is a necessary truth. This may seem paradoxical to some. I stop to justify it.

Physical phenomena we all admit follow one another in unbroken succession, each derived from a preceding, and giving origin to a succeeding. We call this the law of causation, and say that it is axiomatic. We might call it a law of derivation. So also organic *forms* follow one another in continuous chain, each derived from a preceding and giving origin to a succeeding. We call this a law

of derivation. We might call it a *law of causation*, and say that it too is axiomatic. The origins of new phenomena are often obscure, even inexplicable, but we never think to doubt that they have a natural cause; for so to doubt is to doubt the validity of reason, and the rational constitution of Nature. So also the origins of new organic *forms* may be obscure or even inexplicable, but we ought not on that account to doubt that they had a natural cause, and came by a natural process; for so to doubt is also to doubt the validity of reason, and the rational constitution of organic Nature. The law of evolution is naught else than the scientific or, indeed, the rational mode of thinking about the origin of things in every department of Nature. In a word, it is naught else than the law of necessary causation applied to *forms* instead of phenomena. Evolution, therefore, is no longer a school of thought. The words *evolutionism* and *evolutionist* ought not any longer to be used, any more than *gravitationism* and *gravitationist*; for the law of evolution is as certain as the law of gravitation. Nay, it is far more certain. The nexus between *successive events in time* (causation) is far more certain than the nexus between *coexistent objects in space* (gravitation). The former is a *necessary truth*, the latter is usually classed as a contingent truth. I have used and may continue to use the term evolutionist, but if so it is only in deference to the views of many intelligent persons, who do not yet see the certainty of the law.

CHAPTER II.

SPECIAL PROOFS OF EVOLUTION.

Introductory.

It will be seen from the preceding chapter that we regard the law of evolution in its wider sense, viz., the derivative origin of all forms, organic or other, as axiomatic, and therefore requiring no further proof. Among scientific men there is no longer any discussion of the truth of this law, but only of the theories of the causes of the law. We believe that to the scientific mind there is no other rational mode of looking at the subject of origin of organic forms. To such a mind, therefore, all that follows is but the deductive application of that law in the explanation of the phenomena of organic Nature. But it takes time for the popular mind to readjust itself to new and revolutionary truth. Many minds, even among the most intelligent, have not yet accepted this as the only rational mode of thought. Many men require further *special proofs* of the derivative origin of organic forms. Even to those who accept evolution, these proofs will be interesting as illustrations of such origin. We will attempt to bring out these proofs under several heads, the most important of which are: 1. Proofs from morphology, or the general laws of animal structure; 2. Proofs from embryology; 3. Proofs from geographical distribution of organic forms; and, 4. Proofs from artificial breeding. The subject is so vast that all we can do is to touch lightly only the most salient points under each of these heads; for, as we have already said, the evidence is really nothing less than the whole science of biology. Preparatory to this, however, it is necessary to bring out a little more fully than before ([page 29](#)), though still only in outline, the two antagonistic views, which may be called the old and the new, or the natural and the supernatural, of the origin of new organic forms, especially species.

68

Origin of New Organic Forms; the Old View briefly stated.—According to the old-school naturalists, species are the ultimate elements of taxonomy: genera, families, orders, etc., may gradually change their character from age to age, by the introduction of new species; but species were supposed to be substantially *permanent*. It was necessary to have some unit for convenience of description and classification, and this was found to be the best because most stable. As in nearly all cases of beliefs, this doctrine was held at first somewhat loosely, as a provisional and convenient view—as a good working hypothesis—but gradually, under pressure of controversy, became more strictly formulated, and, as it were, hardened into a scientific dogma, especially in the hands of Agassiz. According to this view, the first pair or pairs of each specific kind originated we know not how, but certainly *at once in its present form* in full perfection, and, therefore, presumably by *direct creative* act of Deity; and then afterward by the law of generation continued to produce others of the same pattern indefinitely. Moreover, the first one or more pairs of each kind multiplied and spread abroad in every direction, *each from its own center of origin*, as far as physical conditions and struggle for life with other species would allow. This idea explains tolerably well the geographical distribution of species as we now find it. For example, species on different continents are widely different, because those on each have originated independently where we now find them, and spread in all directions as far as physical conditions would allow, but could not reach other continents because of the ocean-barrier. That this is the only reason they are not there, is shown by the fact that, if they are carried there, they usually do perfectly well. Even on the same continent, for the same reason, species may be very different if separated by impassable barriers such as high mountain-chains or by climate. But wherever one group of species, originating in one place, comes in contact on the margin of their range with another group of species originating in another place, we see no evidence of *transmutation* of one form *into* another, but only *substitution* of one fully-formed species *for* another equally fully formed. Therefore, we must

69

conclude that physical conditions may limit the range of a species, but can not transmute it into another. Thus, to say the least, many of the facts of geographical distribution are well explained by this idea of creative origin in specific centers and subsequent permanence of specific form. We say *many* of the facts; we will show hereafter that *not all* can be thus explained. 70

But the main question is not of geographical but of geological distribution; not distribution in space, but succession in time. Species do not continue forever. On the contrary, they have changed many times in the course of geological history. As conditions become unfavorable, species die out or become extinct, and others take their place and carry forward the life and development of the organic kingdom. Now, how do they change? According to this school of thought, here also, as in geographical distribution, they are not transmuted but replaced; here also physical conditions may destroy a species, but can not transform it into another. As species die out, others are created at once, out of hand and fully formed in their place; but in accordance with a preordained plan consistently carried out and working ever toward higher and higher conditions. Thus, life is continued on the earth by the alternation of supernatural and natural processes; by the alternate use of direct and indirect action of Deity: direct in the introduction of first pairs, indirect through the natural process of reproduction in the continuance and multiplication of the species. Each species is made according to a pattern in the Divine mind, on a sort of intellectual die, and then continues to reproduce a succession of individuals of the same pattern as if struck from the same die until the die is broken or worn out. Another die is made, of another pattern, and individuals are struck from this; and so on, throughout the whole geological history of the organic kingdom. Only, we must add that the successive dies are made to follow one another according to a plan which is expressed by the three laws already given on [page 11](#). Thus, the origin of individuals is natural, the origin of species supernatural; the making of dies is supernatural, the coinage is natural. 71

We have stated this view in a too extreme form, in order to make it clearer. We now, therefore, proceed to qualify somewhat. Specific types were held, by writers of this school of thought, to be *substantially* but not absolutely unchangeable. Successive individuals of the same species were admitted to be not exactly alike. Such slight differences were called *varieties*. It was admitted, indeed, that species varied, but it was believed that such variations in any direction were strictly limited in amount. A species may be compared to a right cylinder standing on end. As such a cylinder may be tilted slightly in one direction or another, without overthrowing its equilibrium, the cylinder tending ever to right itself and return to its original position, so a species may be varied slightly in one direction or another without destroying its integrity, the species tending ever to return to its normal or typical form. But as the cylinder, if pushed too far from its normal position, is overthrown, so also a species, if pressed too far in the way of variation from its typical form, is destroyed, but not changed into another species. As cylinders may be more or less rigid, depending upon the breadth of their bases, so also some species are more rigidly set in their typical form, and some are more plastic to influences causing variations, but in all cases there is a limit to the amount of oscillation consistent with integrity. 72

The New View briefly stated.—According to Darwin, and all biologists of the present day, species are variable *without limit*, if only the causes of change are constant and slow enough in their operation, and the time long enough. A species must be in harmony with its environment, for this is the condition of its existence. Now, if the environment change, the species must *tend* to change slowly from generation to generation, so as to readjust its relations in harmony with the changing environment. If the change of environment be slow, the readjustment may be successful, and the species will change gradually into another form, so different that it will be called a different species, especially if the intermediate gradations be destroyed. If the change in the environment be too rapid, many species, especially the more rigid, will be destroyed, while the more plastic may survive by modification. Thus, at every step in the evolution of the organic kingdom, some species have died without issue, while others have saved themselves by changing into new forms in harmony with the new environment. Comparing to a growing tree, some branches overshadowed die, while others push on for light, forming new lateral buds, and dividing as they grow. By continued divergent change species gradually become genera, genera families, etc. Thus, varieties, species, genera, families, orders, classes, etc., are only different degrees of differences formed all in the same way. Varieties are 73

only commencing species, species commencing genera, and so on. There is no making and wearing out of dies, and making of new ones; the whole process is a natural one—the whole series is genetically connected. In a perfect classification varieties, species, genera, families, orders, classes, etc., are only different *degrees of blood-kinship*.

So much may be regarded as certain, and out of the field of discussion among biologists of the present day. It is only in defining this process more accurately, and especially in the *theory of the causes or factors* of evolution, that there are still difference and discussion. The most probable view on this subject we now proceed to give.

Factors of Evolution.—The causes of change or adaptive modification, or the factors of evolution, are at least *four* well known, and probably many more still unknown: 1. The physical environment—heat and cold, dryness and moisture—affects function of organs, and function affects structure, and both changed function and changed structure are inherited by offspring, and so increased from generation to generation, becoming greater without limit. 2. Increased *use* or *disuse* of organs enforced or permitted by change in the environment, physical or organic, or both, induces change in form, size, and structure of the organs; and this change is inherited by the offspring, and so from generation to generation small differences are integrated until they become great without limit. These two factors were recognized by Lamarck. 3. “Natural selection,” or “survival of the fittest,” among divergent varieties of offspring. This is the distinctive Darwinian factor. In the two preceding factors the change is during the *individual lifetime*, and reproduction is supposed to transmit it unchanged to the offspring. In this factor, on the contrary, the form and structure are supposed to remain unchanged during the individual life, but for some unknown cause there are slight variations in different directions (divergent) in the offspring from the same parents. Now, when we remember that by reproduction the number of individuals tends to increase by geometrical progression, and that in each generation only a very few (on an average only two from all the offspring of one pair) can survive, it is evident that among these divergent varieties those will most likely survive which are most in harmony with the external environment, and which possess the most efficient organs of defense or of escape, or for food-taking. The surviving offspring, therefore, will be on the average better in these respects than their parents. It matters not how little better, for the integration of even infinitesimal improvements from generation to generation will eventually produce any required amount of change. 4. To the above Darwin has added also “*sexual selection*.” In *natural* selection there is struggle of *all* for *food*, or *means of living*. In sexual selection there is a struggle among the *males* for possession of the *female*, and the *means of procreation*. The one is connected with the nutritive appetite, the other with the reproductive appetite. This mode of selection acts in two ways, by the law of battle and the law of attractiveness. The strongest or the most attractive males alone, or mainly, leave offspring, which, of course, inherit their peculiarities; and these are increased indefinitely by integration through successive generations, thus increasing the strength or the beauty. Of these two laws, the law of battle is most conspicuous among mammals, and the law of attractiveness among birds. It is evident that this factor can not operate among many lower animals which are hermaphroditic, nor among plants.

Of these acknowledged factors of evolution, the first two were known to Lamarck and the older evolutionists. The third and fourth are distinctively Darwinian. According to Darwin, while all these are operative, the third is the most powerful; but Spencer accords this distinction to the Lamarckian factors. Many American zoölogists take the same view.

Such until very recently were all the recognized factors of evolution. But, within the past year (1886) has taken place, it seems to us, the most important advance in the theory of evolution since Darwin. It is the suggestion by Mr. Catchpool,¹⁴ and afterward the more full elaboration by Dr. Romanes, of another factor, which he calls “*physiological selection*.”¹⁵

The great objections to the sufficiency of the theory of evolution, as left by Darwin, were twofold: 1. While natural selection accounts completely for the formation of *useful* structures or adaptive modifications, and therefore for differences characterizing classes, orders, families, and even genera—for these are all adaptive—it can not so completely account for those constituting species; for these consist mostly of *trivial* differences in coloration, relative proportion of parts, which are of *no perceivable use* in the struggle for life, and therefore could not be preserved and integrated by natural

selection. Therefore, according to Romanes, natural selection is a theory of origin of adaptive structures rather than of origin of species. Comparing to a growing tree, once admit lateral buds started, and natural selection completely accounts for the growth in different directions, and therefore for the profuse ramification; but the origin of the lateral buds is not explained.

2. The second difficulty is as follows: Such commencing differences as constitute varieties and species not only would not be preserved and integrated by natural selection unless useful, but would immediately be *swamped by cross-breeding* with the parental form. But, as the whole divergence commences in varieties, evidently it could not commence at all unless this cross-breeding be in some way prevented. This may, indeed, be done, without the assumption of any new factor of evolution, by *migration*; and, hence, migration must be regarded as an important agent in the creation of new forms, not only by the effect of a new environment, but also by prevention of the swamping of commencing species by cross-breeding with the parental form; but in a crowded locality, without outlet for migration (the very conditions most favorable for severe competitive struggle, and therefore for most potent operation of natural selection; and therefore, also, according to Darwin, for profuse diversification), commencing varieties could not pass into species, because swamped by cross-breeding. Once the divergence reaches the point of cross-sterility—i. e., of species—then, indeed, by true breeding, characters, even though not useful, may be preserved. But how is it to commence?

This difficulty has been severely felt by all Darwinists. It seems to us that it is largely met by Dr. Romanes. According to Romanes, no organ is so subject to varietal changes as the *reproductive*, and these in no respect so much as in degrees of fertility. Unfortunately, these changes are not visible, and must be judged of only by the results. It is not uncommon, for example, to find sterility between individuals (sexual incompatibility) who are both of them perfectly fertile with other individuals. Similarly, cross-sterility, partial or complete, is not uncommon between varieties or races, as Mr. Darwin has long ago noticed. It very generally, as we know, occurs between, and, in fact, is constantly used as a test of, species. Now, this cross-sterility with parent stock, which we find so constant a character of species, and which, therefore, must *have commenced as a partial cross-sterility* in varieties, is it *antecedent or consequent to other variations*? It has been usual to suppose it consequent to a certain amount of divergence, viz., that which constitutes, or at least approaches, species. But, according to Romanes, it is *antecedent*. Among many other variations, this is that one which originates species, because it prevents reversion by cross-breeding with the parent stock, and insures true breeding with its own kind. In a word, it sexually isolates the species. Suppose, then, a species multiplying indefinitely in one locality: trivial variations of many kinds, and in many directions, occur among the offspring. These are merged by cross-breeding into the original type, which, therefore, remains unchanged. But, from time to time, among these variations there occur some affecting the reproductive organs in such wise as to produce partial or complete cross-sterility with the parent form. This is the beginning of a new species. It breeds true with its own kind, and therefore all the associated variations external and visible, and therefore constituting species, although trivial and of no use in the struggle for life, are preserved.

This view completely accounts for the cross-fertility of artificial breeds equivalent in other respects to species; for cross-sterility is not an end aimed at by the breeder, it being easy to prevent cross-breeding, if desired, by artificial isolation. But, if this view be true, species from widely-different geographical regions ought also to be often cross-fertile, because, having been formed by geographical isolation, sexual isolation was not a necessary factor in their formation. This point deserves testing by careful observation.

It may be, and has been, objected to Dr. Romanes's claims, that this is no new factor; that physiological selection is only a form of natural selection. This objection, it seems to us, is little more than a play upon words. It certainly is selection, and by a *natural* process, and therefore in some sense a natural selection, but not in the sense of Darwin. It is not a selection of individuals *fittest to survive*; for cross-fertile individuals are as fit to survive as individuals, though not as species, as are cross-sterile. Natural selection is intent only on preserving the best individuals; physiological selection on preserving the kind. Natural selection continues the direction of progress unchanged; physiological makes new directions.

In addition to all these factors of *organic* evolution, there is still another far higher factor characteristic of man alone. This is the *conscious, voluntary co-operation of the thing evolving—the spirit of man—in the work of its own evolution*. This may be called the *rational factor*. This, the most important factor of human evolution, is usually ignored by writers on evolution—either as non-existent, or else as lying beyond the domain of science. We will emphasize its importance by taking it up more fully in the next chapter.

80

It will be observed that Darwin and his followers take divergent variations of offspring simply as a known fact, upon which natural selection operates to produce progressive modification; and, as the cause of variation in offspring is wholly unknown, such variations are often spoken of as fortuitous. But, of course, it is well understood that nothing in Nature is really fortuitous. They may, however, for all purposes of natural selection be thus regarded until we know their cause. It is evident, then, that if we, with Darwin, take natural selection, as the most important known factor, the really most important cause of evolution is the *cause* of varieties. This is the *unknown* fundamental factor. As Darwin reduced Agassiz's three formal laws of succession to more general laws of life, and thus made one important step in the advance of biological science, so he who shall explain the *cause* of divergent variation will make another important step by reducing the phenomena to still more general and fundamental laws of life.

In conclusion, let me again impress upon the reader that all the doubt and discussion, above described, as to the factors of evolution, is entirely aside from the truth of evolution itself, concerning which there is no difference of opinion among thinkers.

81

CHAPTER III.

THE GRADES OF THE FACTORS OF EVOLUTION AND THE ORDER OF THEIR APPEARANCE.

We have given in the previous chapter six factors of evolution—viz.: 1. *Pressure of the environment*. 2. *Use and disuse of parts*. 3. *Natural selection*. 4. *Sexual selection*. 5. *Physiological selection*. 6. *Reason*. Let us now compare these as to their grade in the scale of energy and as to the order of their introduction.

The first two or the Lamarckian factors are the lowest in position, the most fundamental and universal, and therefore the first in the order of appearance. They precede all other factors, and were doubtless for a long time *the only ones in operation*. For, observe, all the selective factors—i. e., those of Darwin and Romanes—are conditioned on reproduction; for the changes produced by these are not in the individual during life, but in the offspring at birth. And not only so, but the operations of these factors are further conditioned on *sexual modes* of reproduction; for all the non-sexual modes of reproduction—as, for example, by fissure and by budding—are but slight modifications of growth, and the resulting multitude of organisms may be regarded as in some sense *only an extension of the first individual*. Of course, therefore, the identical characters of the first individual are continued indefinitely, except in so far as they are modified in successive generations by the effect of the environment and by use and disuse—i. e., by the Lamarckian factors. In sexual generation, on the contrary, the characters of two diverse individuals are funded in a common offspring; and the same continuing through successive generations, it is evident that the inheritance in each individual offspring is infinitely multiple. Now, the *tendency to variation* in offspring *is in proportion to the multiplicity of the inheritance*: for among the infinite number of slightly differing characters, as it were, offered for inheritance in each generation, some individuals will inherit more of one and some more of another character. In a word, sexual reproduction by multiple inheritance *tends to variation of offspring, and thus furnishes material for natural selection*.¹⁶

82

Thus, then, I repeat, all the selective factors are absolutely dependent on sexual modes of reproduction. But there was a time when this mode of reproduction did not yet exist.¹⁷ The sexual modes developed out of non-sexual modes. If these non-sexual preceded sexual modes of reproduction, it is evident that at first only Lamarckian factors could operate. Evolution was then carried forward wholly by changes in the individual produced by environment and by use and disuse (acquired characters), inherited and increased by integration through successive generations indefinitely. It is probable, therefore, that the *rate* of evolution was at first comparatively slow; unless, indeed, as seems probable, the *earliest forms were then* and the *lowest forms are now* more plastic under the influence of physical conditions than are the present higher forms. Doubtless, now, in the higher animals and plants, the Darwinian factors are by far the most potent; for, among plants, where we can use these factors separately, if we wish to *make* varieties, we propagate by seeds (sexual reproduction); but, if we wish to preserve varieties, we propagate by buds and cuttings (non-sexual reproduction).

83

I have taken the two Lamarckian factors together, and showed that they preceded the Darwinian. But even in the two Lamarckian factors there is a difference in grade. Undoubtedly the lowest, the most fundamental, and therefore the first introduced, was *pressure of the physical environment*. For use and disuse of organs implies some degree of volition and voluntary motion, and therefore already some advance in the scale of evolution.

With the introduction of sex another entirely different and higher factor was introduced, viz., *natural selection*, or selection of the fittest individuals of a varying progeny. We have already seen how sexual generation produces variation of offspring, and how this furnishes materials for natural selection. As soon, therefore, as this form of generation was evolved, this higher factor came into operation and immediately assumed control; while the previous factors became subordinate, though still underlying, conditioning, and modifying the activity of the higher. The result was an immediate increase in the rate of evolution. It is very worthy of note that it is in the higher animals, such as birds and mammals, in which we have only the highest forms of sexual reproduction, where the diversity of characters of the two sexes funded in the offspring is the greatest, and where, therefore, the variation in offspring is also greatest and natural selection most active; it is precisely among these that the Lamarckian factors are most feeble, because, during the most plastic period of life, the offspring is removed from the influence of the physical environment, and from use and disuse by its inclosure within the womb, or within a large egg surrounded with abundant nutriment. Development is already well advanced before Lamarckian factors can operate at all.

84

Next, I suppose, physiological selection, or Romanes's factor, came into operation. After the introduction of sex, it became necessary that the individuals of some varieties should be isolated in some way, so as to prevent the swamping of varietal characters, as fast as formed, in a common stock, by *cross-breeding*. In very low forms, with slow locomotion, such isolation might easily take place accidentally. Even in higher forms, changes in physical geography or accidental dispersion by winds and currents would often produce geographical isolation, and thus, by preventing crossing with the parent stock, secure the formation of new species from such isolated varieties. But, in order to insure in all cases the preservation of commencing species, *sexual isolation*, or partial or complete infertility of some varieties with other varieties and with the parent stock, was introduced, as I suppose, later. The process by which this takes place has already been explained. According to Romanes, natural selection alone, with cross-breeding, tends to *monotypal* evolution; isolation of some kind is necessary for polytypal evolution. The tree of evolution, under the influence of natural selection alone, grows, palm-like, from its *terminal bud*; isolation of varieties was necessary for the starting of *lateral buds*, and thus for the profuse ramification which is its most conspicuous character.

85

Next, I suppose, was introduced *sexual selection*, or contest among the males, by battle or by display, for possession of the females, and the success of the strongest or the most attractive; and the perpetuation and increase of these superior qualities of strength and beauty in the next generation. This, I suppose, was later, because connected with a higher development of the psychical nature. This is especially true where splendor of color or beauty of song determines the selection. As might be supposed, therefore, this factor is operative only among the highest animals, especially birds and mammals.¹⁸

Next and last, and only with the appearance of *Man*, another entirely different and far higher factor was introduced, viz., *conscious, voluntary co-operation* in the work of his own evolution—a conscious, voluntary striving to *attain an ideal*. We have called this a factor, but it is much more than a mere factor, co-ordinate with other factors. It is, rather, a different kind of evolution. It is evolution on a higher plane and by another nature. As *physical* Nature works *unconsciously*, using certain factors, so *spiritual* nature works *consciously*, co-operating and using the same factors. At first this factor, if we still call it so, was extremely feeble. In the early stages of his progress, man, like other animals, was largely urged on by forces of organic evolution, unknowing and uncaring whither he tended. But more and more, as civilization advances, this higher and distinctively human factor becomes more and more dominant, until now, in civilized communities, it takes control of evolution. Reason, instead of Nature, now assumes control, though still using the methods and factors of Nature. This *free*, self-determined evolution of the race, in order to distinguish it from the *necessary* evolution of the organic kingdom, we call progress.

86

Now, in this whole process we observe two striking stages. The one is the introduction of sex, the other is the introduction of reason.¹⁹ They may be compared to two equally striking stages in the development of the *individual*. As the *ontogenic* evolution receives fresh impulse at the moment of fertilization, so the evolution of the organic kingdom receives fresh impulse at the moment of

87

introduction of sex. As in ontogenic evolution the individual at birth enters upon a new and higher plane, in which it co-operates in its own *physical* growth, so the organic kingdom, with the introduction of man, enters upon a new and higher plane, in which man co-operates in the physical and *spiritual* growth of the race. With sex three new and higher factors were introduced, and these immediately assumed control and quickened the rate of evolution. With reason another and infinitely higher factor is introduced, which, in its turn, assumes control, and not only again quickens the rate, but elevates the whole plane of evolution. Moreover, this voluntary, rational factor not only takes control itself, but transforms all other factors and uses them in a new way and for its own higher purposes.

This last is by far the greatest change which has ever occurred in the history of evolution. In organic evolution Nature operates by necessary law without the conscious voluntary co-operation of the thing evolving. In human progress man voluntarily co-operates with Nature in the work of evolution, and even assumes to take the process mainly into his own hands. Organic evolution is by *necessary* law, human progress by *free* or at least by freer law. Organic evolution is by a *pushing* upward and onward from *below* and *behind*, human progress by a *drawing* upward and onward from above and in front by the attractive force of ideals. In a word, organic evolution is by the law of *force*, human evolution by the law of *love*.

88

It may be well to stop a moment and show briefly some of the differences between organic and human evolution—differences which are, of course, wholly the result of the introduction of this new factor:

1. In organic evolution “*the fittest*” are those most in harmony with the physical environment, and therefore they survive. In human evolution *the fittest* are those most in harmony with *the ideal*, and often, especially in the early stages, when the race is still largely under the dominion of organic factors, they do not survive, because not in harmony with the social environment. But, although the fittest individuals may indeed perish, the *ideal* survives in the race and will eventually triumph.

2. In organic evolution the weak, the sick, the helpless, the unfit in any way perish and *ought to perish*, because this is the most efficient way of strengthening the *blood* or *physical nature* of the species, and thus of carrying forward evolution. In human evolution the weak, the helpless, the sick, the old, the unfit in any way are sustained and *ought to be sustained*, because sympathy, love, pity, strengthen the *spirit* or *moral nature* of the race. But let us remember that in this material world of ours and during this earthly life the spirit or moral nature is conditioned on the physical nature; and, therefore, in all our attempts to help the weak we must be careful to avoid poisoning the blood and weakening the physical vigor of the race by inheritance. This gravest of social problems, viz., How shall we obey the higher law of love and mutual help without weakening the *blood* of the race by inheritance and the spirit of the race by removing the necessity of self-help?—this problem, I believe, can and will be solved by a *rational education*, physical, mental, and moral. I only allude to this. It is too wide a field to follow up here.

89

3. In organic evolution the bodily *form* and *structure* must continually change in order to keep in harmony with the ever-changing environment. In other words, organic evolution is by continual change of species, genera, families, etc. There must be continual evolution of new forms by modification. In human evolution, on the contrary, and more and more as civilization advances, man modifies the environment so as to bring it into harmony with himself and his wants, and therefore there is no necessity of change of bodily form and structure or making of new species of man. Human evolution is not by modification of *form*—new species; but by modification of spirit—new planes of activity, *higher character*. And the spirit is modified and character elevated, not by *pressure* of an *external physical environment*, but by the *attractive force* of an *internal spiritual ideal*.

90

4. The way of evolution toward the highest—i. e., from protozoan to man and from lowest man to the ideal, the divine man—is a very *straight and narrow way*, and few there be that find it. In the case of organic evolution it is so straight and so narrow that any divergence therefrom is fatal to upward movement toward man. Once get off the track, and it is *impossible* to get on again. No living form of animal is on its way *manward*, or can by any possibility develop into man. They are all gone out of the

way. There is none going right; no, not one. The organic kingdom developing through all geological times may be compared to a tree whose trunk is deeply buried in the lowest strata, whose great limbs were separated in early geological times, whose secondary branches diverged in middle geological times, and whose extreme twiglets, and also its graceful foliage, its beautiful flowers, and luscious fruits, are the fauna and flora of the present day. But this tree of evolution is an *excurrent stem*, continuous through the clustering branches to the terminal shoot—man. Once leave the stem as a branch, and it is easy to continue growing in the direction chosen, but impossible to get back on the straight upward way to the highest. In human evolution, whether individual or racial, the same law holds, but with a difference. If individual or race gets off the straight, narrow way toward the highest—the divine ideal—it is hard, very hard to get back on the track. Hard, I say, but *not* impossible, because man's conscious voluntary effort is the chief factor in his own evolution. By virtue of self-activity, through the use of reason and co-operation in the work of evolution, man alone of all created things is able to rectify an error of direction and return again to the deserted way.

91

5. In organic evolution, when a higher factor appears, it immediately assumes control, and previous lower factors sink into a subordinate position, though still underlying and conditioning the higher. But in human evolution, the higher rational factor, when it comes in with man, not only assumes control, but transforms all other factors and uses them in a new way and for its own higher purposes. In fact, as already said, it is much more than a mere factor. It determines a new kind of evolution—evolution on a new and higher plane though, indeed, underlaid and conditioned by the laws of organic evolution. As *external physical* Nature uses many factors to carry forward organic evolution, so the *internal spiritual* nature, characteristic of man alone, uses these same factors in a new way to carry forward human evolution or progress. Thus, for example, one organic factor—the environment—is modified or even totally changed so as to effect suitably the human organism. This is *hygiene*. Again, use and disuse—another factor—is similarly transformed. The various organs of the body and faculties of the mind are deliberately used in such wise and degree (determined by reason) as to produce the highest efficiency of each part and the greatest strength and beauty of the whole. This is *education*—physical, mental, moral. So also the selective factors are similarly transformed, and *natural* selection becomes *rational* selection. We all know how this method is applied to domestic animals and cultivated plants in the formation of useful or beautiful varieties. Why should it not be applied also to the improvement of our race in the selection of our mates in marriage, or in the selection of our teachers, our law-makers, our rulers? Alas! how little even yet does reason control our selection in these matters! How largely are we yet under the law of organic evolution!

92

Application of these principles to some questions of the day:

I. Evolution, as a law of derivation of organic forms from previous forms by descent with modifications, as already shown, is as certain as the law of gravitation. This question has passed beyond the realm of doubtful discussion; but the causes, the factors, the details of the process of evolution are still under discussion. Both Darwin and Spencer, the two great founders of the theory of evolution in its modern form, acknowledge and insist on at least four factors, viz., the two Lamarckian and the two distinctively Darwinian. The only difference between them is in the relative importance of the two sets: Spencer regarding the former and Darwin the latter as the more potent. But in these latest times there has arisen a class of biologists, including some of highest rank, such as Wallace, Weismann, and Lankester, who out-Darwin Darwin himself in their exaltation of the most distinctive Darwinian factor, viz., natural selection. They try to show that natural selection is the sole and sufficient cause of evolution; that changes in the individual, whether as the effect of the environment or by use and disuse of organs, are not inherited at all; that Lamarck was wholly wrong; that Darwin (in connection with Wallace) was the sole founder of the true theory of evolution; and, finally, that Darwin himself was wrong only in making any terms whatever with Lamarck. This view has been called *Neo-Darwinism*.

93

Perhaps the reasons for this view have been most strongly put by Weismann, and are based partly on experiments, but mainly on his ingenious and now celebrated theory of the immortality of germ-plasm. The animal body consists of two kinds of cells wholly different in function—somatic cells and germ-cells, including in this last the sexual elements both male and female. Somatic cells are specially

modified for the various functions of the body; germ-cells are wholly unmodified. The somatic cells are for the conservation of the *individual* life, the germ-cells for the conservation of the *species*. In the development of the egg the germ-cell multiplies itself into a cell-aggregate, and then most of the resulting multitude of cells are modified in various ways to form the tissues and organs of the body—somatic cells; but a few are reserved and put aside in an unmodified form in the sexual organs as germ-cells, to again produce ova which again divide into somatic and germ-cells, and so on indefinitely. Now, according to Weismann, inheritance is only through *germ-cells*, while the environment affects only the *somatic cells*. Therefore changes produced by the environment can not be inherited. Sexual modes of generation were introduced for the purpose of producing variability in progeny, and thus furnishing material for natural selection, as this was the only means of evolutionary advance. Weismann made many experiments on animals, especially by mutilation, to show that somatic changes are not inherited.

94

A full discussion of this question would be unsuitable in a work like this. We will therefore content ourselves with making three brief remarks:

a. If the views presented in the early part of this chapter are true, then the Lamarckian factors must be true factors, *because there was a time when there were no others*. They were therefore necessary, at least to start the process, even if no longer necessary at present.

b. But if these factors were ever operative, *they must be so still*, though possibly in a subordinate degree. A lower factor is not abolished, but only becomes subordinate to a higher when the latter is introduced. Thus it may well be that Lamarckian factors are comparatively feeble at the present time and among living species, especially of the higher animals, and yet not absent altogether. In the earliest stages of evolution there was a *complete identification of germ-cells and somatic cells*—of the individual with the species. In such cases, of course, any effect of the environment must be inherited and increased from generation to generation. But the differentiation of the germ and somatic cells was not all at once, nor is their sympathetic relation completely severed. It was a *gradual process*, and therefore the effect of the environment *on the germ-cells through the somatic cells* continued, though in decreasing degree, and still continues. The differentiation in the higher animals is now so complete that germ-cells are probably not at all affected by changes in somatic cells, unless these changes are *long continued in the same direction, and are not antagonized by natural selection*.

95

c. It is a general principle of evolution that the *law of the whole is repeated with modifications in the part*. This is a necessary consequence of the unity of Nature. We ought to expect, therefore, and do find, that the order of the use of the factors of evolution is the same in the evolution of the *organic kingdom*, in the evolution of *each species*, and in the evolution of *each individual*. In all these the physical factors are at first powerfully operative; these become subordinate to organic factors, and these, in their turn, to psychical and rational factors. Therefore, as the individual in its early stages—i. e., in embryo and infancy—is peculiarly plastic under the influence of the physical environment, and afterward becomes more and more independent of these; so a species when first formed is more plastic under the influences of Lamarckian factors, and afterward becomes more rigid to the same. And so also the organic kingdom was at first more plastic under Lamarckian factors, and has become less so in the present species, especially in the higher animals. The principal reason of this, as we have already seen, is the increasing differentiation of germ and somatic cells, and the removal of the former to the interior, where they are more and more protected from external influence.

96

II. Some evolutionists—the materialistic—insist on making human evolution identical in all respects with organic evolution. This, we have shown, is not true. The very least that can be said is that a new and far more potent factor is introduced with man, which modifies greatly the process. But we may claim much more, viz., that evolution is here on a different and higher plane. The factors of organic evolution are, indeed, still present, and condition the whole process; but they are not left to be used by Nature alone. On the contrary, they are used in a new way and for higher purposes—by reason.

But by a revulsion from the materialistic extreme some have gone to the opposite extreme. They would place human progress and organic evolution in violent antagonism, as if subject to entirely

different and even opposite laws; but we have also shown that, although the distinctive human factor is indeed dominant, yet it is underlaid and conditioned by all the lower factors; that these lower factors are still necessary as the agents used by reason.

III. We have already given the views of Weismann and Wallace, and some reasons for not accepting them; but there is one important aspect not yet touched. There are some logical consequences of these views when applied to human evolution which seem to us nothing less than a *reductio ad absurdum*. This brings into view still another contrast between organic evolution and human progress. 97

In organic evolution, when the struggle for life is fierce and pitiless as it is now among the higher animals, natural selection is undoubtedly by far the most potent factor. It is at least conceivable (though not probable) that at the present time organic evolution might be carried on mainly or even wholly by this factor alone; but in human evolution, especially in civilized communities, this is impossible. If Weismann and Wallace be right, then alas for all our hopes of race improvement—physical, mental, and moral!—for natural selection will never be applied by man to himself as it is by Nature to organisms. His spiritual nature forbids. Reason may freely use the Lamarckian factors of environment and of use and disuse, but is debarred the unscrupulous use of natural selection *as its only method*. As this is an important point, we must explain.

All enlightened schemes of physical culture and hygiene, although directed primarily to secure the strength, the health, and the happiness of the *present generation*, yet are sustained and ennobled by the conviction that the improvement of the individuals of each generation enters by inheritance into the gradual physical improvement of the race. All our schemes of education, intellectual and moral, though certainly intended mainly for the improvement of the individual, are glorified by the hope that the race also is thereby gradually elevated. It is true that these hopes are usually extravagant; it is true that the *whole* improvement of one generation is not carried over by inheritance into the next; it is true, therefore, that we can not by education raise a lower race up to the plane of a higher in a few generations or even in a few centuries: but there must be at least a small residuum, be it ever so small, carried forward from each generation to the next, which, accumulating from age to age, determines the slow evolution of the race. Such are the hopes on which all noble efforts for race-improvement are founded. Are all these hopes baseless? They are so if Weismann and Wallace are right. If it be true that reason must direct the course of human progress, and if it be true also that selection of the fittest in the organic sense is the only method which can be used by reason, then the dreadful law of pitiless destruction of the weak, the helpless, the sick, the old, must with Spartan firmness be voluntarily and deliberately carried out. Against such a course we instinctively revolt with horror, because contrary to the law of our spiritual nature. 98

But the use by reason of the Lamarckian factors is not attended with any such revolting consequences. All our hopes of race-improvement, therefore, are strictly conditioned on the efficacy of these factors—i. e., on the fact that useful changes, determined by education in each generation, are to some extent inherited and accumulated in the race.

CHAPTER IV.

SPECIAL PROOFS, TAKEN FROM THE GENERAL LAWS OF ANIMAL STRUCTURE, OR FROM COMPARISON IN THE TAXONOMIC SERIES.

General Principles.

Analogy and Homology.—In biology those organs or parts in different animals are said to be *analogous* which, however different their origin, have a general similarity of form and especially of function; while those are called *homologous* which, however different their general appearance, and however different their function, yet may, by close examination and extensive comparison, be shown to be modifications of one another—to be, in fact, originally the same part modified for different purposes. In the former the parts compared look and behave as if they were the same, but are not; in the latter they look and behave entirely differently, but are, in fact, the same part in disguise.

We can best make this plain by examples. The wing of a bird and the wing of a butterfly are analogous organs. They have the same function—i. e., flying; and this function necessitates the same general form of a flat plane. But they are not at all homologous; they are not at all the same organ or part. They certainly have never been formed one out of the other by modification. But the wing of a bird, the fore-paw of a reptile or mammal, the wing of a bat, and the arm and hand of a man, though so different in form and function, are homologous parts. On close examination they are found to have the same general structure, to be composed of essentially the same pieces, although they are so greatly modified in order to adapt them to different functions, that the general or superficial resemblance is now lost. Their structure is precisely such as it would be if they had all originated from some archetypal fore-limb by modifications in different directions of its several parts. By extensive comparison in the taxonomic and ontogenic series, all the intermediate gradations between these extreme modifications may be picked up.

100

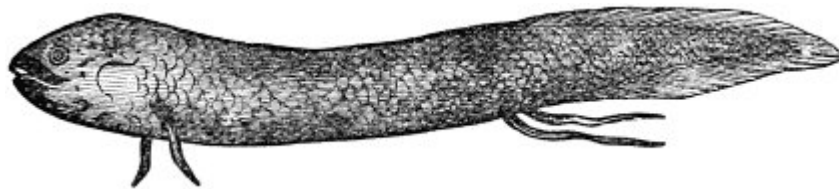


FIG. 2.—Lepidosiren.

Another example. The lungs of a mammal and the gills of a fish are analogous organs, since they have the same function of aëration of the blood. But they are not at all homologous: they are not built on the same plan; by no effort of the mind can we imagine that the former could have come out of the latter by modification. On the contrary, we have positive proof that it did not so come. But there is an organ in the fish which is homologous with the mammalian lung, viz., the air-bladder, or swim-bladder. We know it—1. Because we can trace in the taxonomic series all the gradations from the one to the other. In most fishes the air-bladder is wholly cut off from the gullet, and only very feebly supplied with blood. It is used and can be used only for flotation. In others, as the gar-pike, the swim-bladder is quite vascular and opens by a tube into the throat. Through this opening air is gulped down from time to time into the bladder, and again from time to time expelled. In other words, this fish

101

supplements its gill-breathing by an imperfect lung-breathing. We have here the beginning of a lung. In still other fishes, viz., the Dipnoi (*lepidosiren* and *ceratodus*, [Fig. 2](#)), the air-bladder becomes a more perfect lung—i. e., a very vascular sacculated sac; and there is not only an opening into the throat, but also from the throat to the snout. In other words, we have for the first time *nostrils*. These fishes completely combine gill-breathing with lung-breathing. The step from these to the lowest amphibian reptiles is so small, that some have classed the *lepidosiren* among amphibians instead of fishes. The *siredon* or axolotl of New Mexico, the *necturus* or *menobranchus* of our Northern lakes, and the *siren* of our Southern swamps, have both gills and lungs, and breathe both air and water; but the lung is very imperfect, being only a sacculated sac, like the air-bladder of the *ceratodus* and *lepidosiren*. No one doubts that the air-breathing organ of an amphibian is a true lung; yet we have traced all the gradations between it and the air-bladder of a fish. We conclude, therefore, that if there be any such thing as transmutation of organic forms, the lung of higher animals must have been formed by the process above described.²⁰

102

But we know it still more certainly—2. Because we can trace the change from the one to the other in the ontogenic series. In the life-history of the individual we can actually see the one thing change into the other. The frog, as is well known, when first hatched, is a tadpole. It has no legs, but locomotes by means of a vertically-expanded tail. It has no lungs, but breathes water instead of air, by means of gills. It is in all respects, therefore, a fish, and would be classed as such if it remained in this condition. But it does not; it gradually loses its tail and gills, and acquires legs and lungs, and breathes air only. Now in this change whence came the lungs? From the gills by modification? No; but from an organ similar in character and position to the air-bladder of a *ceratodus*, or a *lepidosiren*. This organ has gradually developed into a lung. The steps of the change are briefly as follow: First, the breathing is wholly water-breathing by gills. Next, by the development of this other organ, it is partly water-breathing by gills, and partly air-breathing by lungs. Lastly, the gills gradually dry up, and the lungs develop more and more, until the breathing is wholly by lungs.

103

We have dwelt somewhat upon this example, because it is an excellent example of what we mean by homology, and also because we will have occasion to use it again. But so important, for all that follows in this part, is a clear idea on the subject of homology, that it will be best to familiarize the mind of the reader with it by means of a few examples drawn from plants.

A potato is analogous to a root—a tuberous root like that of a dahlia or a sweet-potato—but is not at all homologous with these. On the contrary, it is homologous with a stem. It is essentially an underground, leafless branch, which has thickened enormously at the point by accumulation of starch. The evidence of this is found in the fact that it has rudimentary leaves (scales) arranged in regular spiral order of phylotaxis, each with its axillary bud (eyes). It is still more clearly shown by the fact that buds above-ground which, if let alone, would form leafy branches, may be made to become tubers by covering them with earth or dead leaves, and thus excluding the light; and, conversely, underground buds which, if let alone, would form tubers, may be made to grow into leafy branches by exposing them to the light.

Take another example: The broad, flat, elliptical, green masses so characteristic of the cactus family, and usually called their leaves, are indeed *analogous* to leaves in color, form, and function; for they are green and flat, and assimilate carbonic acid and water (CO₂ and H₂O) like leaves. But they are not, in truth, leaves, but modified stems, for they have the essential structure of stems, with their pith, wood, medullary rays, and bark, and may be traced through all gradations into the ordinary cylindrical form of stems. Where are their leaves, then? Their spines are their abortive leaves. These are arranged spirally like leaves, and bear buds in their axils like leaves. They are, in truth, leaves, modified to perform the function of defensive armor; while their function has been delegated to the stem flattened for this purpose.

104



FIG. 3.—A branch of young acacia, showing change from one form of leaf to the other; *a, b, c, d*, successive stages of change; *l, s*, leaf stalk which gradually changes into the blade in *c, d*, and *e*.

One more example: The acacias, of which there are fifteen to twenty species in California, introduced from Australia, form two groups having extremely different styles of leaves. We will call them the feather-leaved and the simple-leaved acacias. In the former, the leaves are very finely bipinnate, and the general aspect of the foliage is extremely feathery and graceful. In the latter the leaves are simple, ovate, and, curiously enough, set on edge; and the general aspect of the tree is therefore rather stiff. It seems at first incredible that leaves so different and aspects so diverse should belong to plants of the same genus. But a little close examination shows that, as usual, the botanists are right and the popular judgment wrong. The plumose-leaf is the normal leaf-form for this genus. The simple leaf is not only abnormal, but in a homological sense is not a leaf at all—i. e., it does not correspond to the part called the *blade* in ordinary simple leaves of other trees. In the seedling of the simple-leaved acacias, and sometimes for a considerable time in the young tree, the leaves are all plumose. As the tree matures it gradually changes its dress and puts on its *toga virilis*. The gradual change from the one form to the other may easily be traced in the same tree, and even often in the same branch ([Fig. 3](#)). The steps of the change (*a, b, c*, and *d*) are shown in the following figure, drawn from nature. It is seen, by bare inspection of the figure, that the so-called leaf, *d*, of the simple-leaved acacias, is really the vertically-expanded leaf-stalk, *l, s*, the true leaf or blade being wholly aborted. The whole structure of this so-called leaf is different from that of a true blade. For example, its style of ribbing is parallel, its position is edgewise to the sky, its palisade cells are on both sides alike, etc. To emphasize this difference, botanists call such an apparent leaf a *phyllodium*, or phyllode.

105

106

After these illustrations we now repeat the definitions in different words. Analogy has reference to *general resemblance* of form determined by *similarity of function*, however different the origins of the parts compared may be. Homology has reference to *community of origin*, however obscured to the superficial observer such common origin may be by modifications necessary to adapt to different

functions. Observe, then, there are two ideas here which must be kept distinct. One is common origin, always shown by deep-lying, essential identity of structure; the other is adaptive modification for function. Organs of the most diverse origin may resemble by adaptive modification for the same function. This is analogy. Organs of the same origin may assume very different appearance by adaptive modifications for different functions. This is homology. In the latter case, which is the one that concerns us, a profound study of essential structure and structural relations to other parts, and especially extensive comparison in the taxonomic and ontogenic series, will usually detect the homology, or common origin, in spite of the obscurations produced by adaptive modifications. It is seen, also, that analogy is a superficial resemblance, easily detected by the popular eye, and therefore embodied in popular language; while homology is a deep-seated and essential resemblance, detected often only by profound study and extensive comparison. Now, one of the strongest proofs of the truth of evolution is taken from the homologies of animal structure. Common origin completely explains homology. Every other explanation is transcendental, and therefore unscientific.

107

Primary Divisions of the Animal Kingdom.—Now, the animal kingdom consists of several primary divisions, called sub-kingdoms or departments. The animals in these groups differ so essentially from one another in their *plan of structure*, that it is difficult, if not impossible, to trace any structural relation between them—to imagine how the members of one could have been derived from those of another—or conceive the common stem from which they all separated. In other words, it is impossible, in the present state of knowledge, to trace homology with any certainty from one group to another. But within the limits of each primary group the homology is easy. Some naturalists—Agassiz and Cuvier—have made four or five of these primary groups. Some—Huxley—have made eight. Some make nine or ten.²¹ We will not trouble ourselves to settle this question; for all agree to make *vertebrata* and *articulata* or *arthropoda* two of them, and all our illustrations will be drawn from these. Other groups are too unfamiliar to the general reader to serve our purpose.

108

Now, as already stated, homology can not be traced with any certainty between the primary groups, but within the limits of each group it may be traced with ease and beauty. Analogy, however, being connected with function, and function being universal, can be traced throughout the animal kingdom. While, therefore, it is probable, nay, almost certain, that all animals have had a common origin, we can not yet trace these great departments by homology to that common origin. But the common origin of each department is quite clear. For example, the structure of all vertebrate animals is precisely such as would be the case if all came from one primal vertebrate, variously modified to adapt to various modes of life. Also, the structure of all arthropods is precisely such as would be if all came from one primal arthropod, which, from generation to generation, became gradually modified in different directions, in order to adapt itself to various modes of life. But between arthropods and vertebrates we can not yet clearly see a common origin, although there doubtless was such.

109

These great departments may, therefore, be compared to *natural styles of animal architecture*. As there are various styles of human architecture—Oriental, Egyptian, Greek, Gothic—each of which may be variously modified to adapt it to all the different purposes for which buildings are made, without destroying, though perhaps obscuring, the integrity of the style; so the different primary groups or departments may be regarded as different styles of animal structure, each of which may be and has been modified in many ways to adapt it to various habits and modes of life, obscuring but not destroying the general style. Or they may be compared to natural *machines*. As a steam-engine, by modification, may be adapted to many kinds of purposes, obscuring, perhaps, but not destroying the essential identity of structure; even so the vertebrate machine by modification may be, and has been, adapted to many kinds of purposes, and thus become a swimming-machine, a crawling-machine, a flying-machine, a running-and leaping-machine, without destroying, although obscuring, the essential identity of structure. As in architecture, æsthetic principles of form may be traced through each style, but not from style to style, while the mechanical principles of construction run through all alike; so also in animal architecture, the laws of form and styles of structure are traceable with ease only within the limits of each primary group, while the laws of function are traceable through all groups alike. Or, again, and finally: Each of these departments may be compared to a *tree*, with branches, twigs, and spray, all obviously coming from one common stem, but each stem seems separate. They are, indeed, probably, themselves only great branches of one common trunk, but their connection is too remote and

110

obscure to be made out clearly by means of homology. Other evidences, however, drawn from other sources, as we shall see hereafter, are not wholly wanting.

CHAPTER V.

PROOFS FROM HOMOLOGIES OF THE VERTEBRATE SKELETON.

The proposition to be established here is, that all vertebrates have not only a common general plan of structure, but an essential identity even in detail, although this identity is obscured by adaptive modifications. We will try to show first a common general plan, and then, taking parts most familiar to the general reader, will show essential identity even in detail.

Common General Plan.—1. All vertebrate animals, and none other, have an *internal* jointed skeleton worked by muscles on the *outside*. As we shall see hereafter, the relation of skeleton and muscle in arthropods is exactly the reverse.

2. In all vertebrates, and in none other, the axis of this skeleton is a jointed backbone (vertebral column) inclosing and protecting the nervous centers (cerebro-spinal axis). These, therefore, may well be called back-boned animals.

3. All vertebrates, and none other, have a number of their anterior vertebral joints enlarged and consolidated into a box to form the skull,²² in order to inclose and protect a similar enlargement of the nervous center, viz., the brain; and also usually, but not always, a number of posterior joints, enlarged and consolidated to form the pelvis, to serve as a firm support to the hind-limbs.

4. All vertebrates, and none other, have two cavities, inclosed and protected by the skeleton, viz., the neural cavity above, and the visceral or body cavity below, the vertebral column; so that a cross-section of the body is diagrammatically represented by [Fig. 4](#).

112

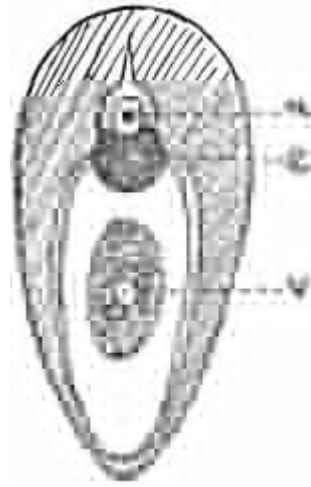


FIG. 4.—Diagram cross-section through the body of a vertebrate, showing the relation of skeleton to the cavities.
***n*, neutral cavity;**
***v*, visceral cavity;**
***c*, centrum of vertebra.**

5. All vertebrates, with few exceptions, and no other animals, have two and only two pair of limbs. The exceptions are of two kinds, viz.: *a*, some lowest fishes, amphioxus and lampreys, which probably represent the vertebrate condition before limbs were acquired; and *b*, degenerate forms like snakes and some lizards, which have lost their limbs by disuse.

So much concerns the general plan of skeletal structures, and is strongly suggestive of—in fact, is inexplicable without—common origin. But much more remains which is not only suggestive, but demonstrative of such origin. By extensive comparison in the taxonomic and ontogenic series, the whole vertebrate structure in all its details in different animals may be shown to be modifications one of another. Sometimes a piece is enlarged, sometimes diminished, or even becomes obsolete; sometimes several pieces are consolidated into one; but, in spite of all these obscurations, corresponding parts may usually be made out. This is the main subject of this chapter.

113

Special Homology of Vertebrate Limbs.—It would lead us much too far into unfamiliar technicalities to take up the whole skeleton. We select the limbs, both because their general structure is more familiar, and because in them the two fundamental ideas of essential identity and of adaptive modification are both admirably illustrated. The reason of this is, that it is by the limbs that the organism chiefly reacts on the environment, and is modified by it.

Fore-limbs.—In the accompanying figures ([Figs. 5–18](#)) we have represented, side by side, the fore-limbs of many vertebrates, taken from all the classes—mammals, birds, reptiles, and fishes. For convenience of comparison, the corresponding parts are similarly lettered in all. Also, in order to identify easily certain important corresponding segments, we have drawn through them a continuous dotted line. In man, nearly all the parts are present, and his limbs, therefore, may be taken as a term of comparison; for man's structure, except his brain, is far less modified than that of many animals.

Note, then, the following points: 1. The collar-bone (clavicle) is associated with wide separation of the shoulders, and the free use of the fore-limb for prehension or for flight, but is gradually lost in proportion as the fore-limb is brought nearer together and used for support, because it is no longer wanted. I say *gradually*, for all the steps of the passing away may be found. The useless rudimentary condition is not uncommon. 114

FIGS. 5–9.—5. Fore-limb of man. 6. Dog 7. Hog. 8. Sheep. 9. Horse. *sc*, scapula; *c*, coracoid; *a*, *b*, two bones of fore-arm. (Taken from various sources and grouped.)

FIGS. 10–13.—10. Fore-limb of bat. 11. Bird. 12. Archæopteryx. 13. Pterodactyl. (Lettered as in previous figures; grouped from various sources.)

2. The coracoid (*c*), it is seen, is a small, beak-like process of the blade-bone (scapula) in man and mammals; but in birds ([Fig. 11](#)) and reptiles ([Figs. 14, 18](#)) it is a separate bone as large as the blade-bone itself, jointed with the latter at the shoulder and with the breast-bone (sternum) in front, thus making together a strong shoulder-girdle for the attachment of the fore-limb. This was undoubtedly the condition in the original or earliest walking animal, viz., reptiles. It was inherited and retained by birds, because necessary for powerful action of the wings in flight. In mammals it gradually dwindled and became united with the blade-bone as a process. In one mammal, the lowest and most reptilian living—the ornithorhynchus—the coracoid is much like that of reptiles—a large, flat bone, separated from the blade-bone and articulated with the breast-bone. It is a significant fact that, in the mammalian embryo, it is first developed as a separate bone and afterward united with the scapula.

116

FIGS. 14–17.—14. Fore-limb of turtle. 15. Mole. 16. Whale. 17. Fish.

3. In man, monkeys, bears, and some other mammals, the limb is fairly free from the body and the elbow half-way down the limb; while in herbivores ([Figs. 8, 9](#)), such as the horse, ox, and deer, etc., the elbow is high on the side of the body, and the limb is free only from the elbow downward. Perhaps in these cases most observers do not recognize it as an elbow at all. All gradations between these extremes are easily traced. The free condition of the limb is evidently the original one, the condition in herbivores being an extreme modification associated with another modification mentioned under 5. 117

4. In man and in many mammals, and in all reptiles and birds, there are two bones in the forearm (radius and ulna). In the more specialized forms of hoofed animals (ungulates), such as horse and ruminants ([Figs. 8, 9](#)), there is apparently but one. Two is the normal and original number; but one of them, the ulna, has gradually become smaller and smaller, and finally is reduced to a short splint, and consolidated with the radius as a process extending backward to form the point of the elbow. In the horse family every step of this reduction and consolidation may be traced in the course of its geological history.

FIG. 18.—Mosasaur.

5. The *wrist* of many mammals and all birds differs in structure from that of man, chiefly in containing a smaller number of bones. The normal number, as in man, seems to be eight. The decrease takes place mainly by consolidation of two or more into one. In such cases usually the embryo will show the bones still separate, thus revealing the ancestral condition. Again, the *position* of the wrist is noteworthy. In man, monkeys, the bear family, and several other mammalian families, and in all reptiles, the hand bends forward at the wrist, so that the tread is on the whole palm (palmigrade). But, in all the most specialized mammals, the wrist can not bend in this direction, and therefore this joint can not be brought to the ground. The tread is therefore on the toes (digitigrade), and the wrist is high up above the ground. In the horse ([Fig. 9](#)), the ox, and many other mammals, for example, the wrist is so high that it is not usually recognized as a wrist, and is often called the *fore-knee*. Now, homologous parts ought to have the same *scientific* name; but to use the word "*hand*" in the case of lower animals might produce confusion and misconception. Therefore it has been agreed among comparative anatomists to use instead the Latin word "*manus*" for all that corresponds, in any animal, to the hand of man—i. e., all from the wrist downward. The manus of a horse is about fifteen inches long. The manus of a pterodactyl, such as that found by Marsh in the cretaceous strata of the West, with an expanse of wings of twenty-five feet, was probably not less than seven or eight feet long. 118

6. The number of palm-bones (metapodal) and toes deserves special notice. In fishes, and in some extinct swimming reptiles, these are or were very numerous, but in the earliest land-animals they became five. This is the number now in nearly all reptiles, and in all the more generalized mammals. It may be called the normal number for a walking animal. In very many mammals, such, for example, as the dog family, they are reduced to four, though the fifth often remains as a useless, rudimentary splint and dew-claw ([Fig. 6](#)), thus showing the process of dwindling in the ancestry. In hoofed animals the process of gradual diminution is shown even in existing forms, and still better in extinct forms. Confining ourselves, now, only to existing forms, in the elephant there are five palm-bones and toes, and in the hippopotamus there are four, all functional. In the hog ([Fig. 7](#)) there are still four, but two are behind the others and much smaller, and do not touch the ground—are not functional unless in soft 119

ground. In the cow, deer, etc., the palm-bones are reduced to two, and these are consolidated into *one* (canon-bone), and the toes are reduced to two efficient and two useless rudiments. In the sheep and the goat ([Fig. 8](#)) these useless rudiments are dropped, and there are two only. Finally, in the horse ([Fig. 9](#)), the *toes* are reduced to one, although the palm-bones are still three, two of them, however, being reduced to rudimentary splints.

How is it with birds? Have these also palm-bones and fingers? Yes, in birds ([Fig. 11](#)) there are three palm-bones and three fingers (the fourth and fifth being wanting); one of them—the thumb—is free, and sometimes carries a claw. In the earliest known and most reptilian bird, the archæopteryx ([Fig. 12](#)), all the three fingers are free, have the full number of joints, and all of them carry claws. In the embryo of living birds the fingers are all free, as in the archæopteryx.

120

FIG. 19.—Restoration of Rhamphorhynchus phyllurus (after Marsh). One-seventh natural size.

7. Observe, finally, as an admirable illustration of different adaptative modifications for the same purpose—flight—the structure of the manus of flying animals. In the bat ([Fig. 10](#)), the flat flying-plane is made by enormous elongation of the palm-bones and finger-bones, their wide separation and the stretching of a thin membrane between them. In the pterosaurs, or extinct flying reptiles ([Fig. 13](#)), one finger only is greatly enlarged and elongated, and the flying-membrane is stretched between it and the hind-leg ([Fig. 19](#)), while the other three fingers are free and provided with claws. If it be asked which finger is it that is so greatly enlarged in this animal, we answer, it is the *little finger*. In birds, on the contrary, the manus is consolidated to the last degree, to form a strong basis for attachments for the quills which form the flying-plane, and which are themselves extreme modifications of the scales of reptiles. But throughout all these extreme modifications the same essential structure is detectable.

121

It is perhaps unnecessary to dwell upon the still greater modifications of limbs for swimming, as in the whale ([Fig. 16](#)), the ichthyosaur, mosasaur ([Fig. 18](#)), and the fish ([Fig. 17](#)). A careful inspection of the figures, after what we have said, will be sufficient to explain them. In the fish alone the upper segments of the limb, viz., shoulder-girdle and humerus, are wanting, not being yet introduced, and the manus is not yet differentiated into palm-bones and fingers, and the fingers are indefinitely multiplied. All these characters are indications of low position in the scale of evolution. The earliest vertebrates were fishes. Limbs were not yet completely formed. In embryos of higher animals, also, the outer segments are first formed.

Hind-Limbs.—[Figs. 20 to 24](#) represent, in a similar way, the hind-limbs of several animals—in this case all mammals. As before, corresponding parts are similarly lettered, and a dotted line is carried through certain prominent parts, especially the knee, heel, instep, and toes. By careful inspection the figures explain themselves. Nevertheless, it will be well to draw special attention to several of the more important points:

122

FIGS. 20–24.—20. Hind-limb of man. 21. Monkey. 22. Dog. 23. Sheep. 24. Horse.

1. See, then, the position of the knee. The thigh-bone in man, monkeys, bears, and several other families of mammals, and all reptiles, is free from the body, and the knee is far removed and half-way down the limb ([Figs. 20, 21](#)). This is undoubtedly the original and normal condition of land-animals. But in all the more highly specialized and swifter animals the knee is brought nearer and nearer to the body, until, in the swiftest of all, such as the ruminants and the horse ([Figs. 23, 24](#)), it is high up on the side of the body, in the middle of what is usually called the thigh but which really includes the thigh and the upper part of the lower leg or shank.

123

2. See, again, the position of the heel. In man, monkey, bear, and many other mammals, and all *living* reptiles, the heel is on the ground, the tread is on the whole foot, plantigrade; while in all the more specialized and agile animals, and especially in the swiftest of all, such as the horse, the deer, etc., the heel is high in the air, and the tread is digitigrade.

3. Observe, again: there are two degrees of digitigradeness. The one we find in carnivorous or clawed digitigrades, the other in herbivores or hoofed digitigrades. In the one the tread is on the whole length of the toes to the balls, as in man when he *tip-toes*; in the other the *tread is on the tip of the last joint alone*. All that in any animal corresponds to the foot of a man—i. e., from the hamstring and heel downward—is called, in comparative anatomy, the “*pes*.” The *pes*, or foot of a horse, is eighteen inches long. It is easy to see what spring and activity this mode of treading gives to an animal. Think how helpless a horse would be if he trod on the whole foot, heel down!

4. Observe, again, the number of toes. In the process of specialization there is a tendency for these to become fewer and stronger.²³ The normal number, as already seen, is five. All the earliest mammals, and many orders of mammals still living, have five; but in the most specialized orders, such as the ungulates or hoofed animals, they were steadily reduced in number in the course of evolution. In the elephant there are still five, in the hippopotamus there are four, in the rhinoceros three, in the goat two, in the horse one. Still more the order of the dropping is regular. If an animal have but four toes, it is usually the first, or great toe, or thumb, that is wanting, or may be rudimentary. If, as in the rhinoceros, there are only three, then No. 5, or little toe, is also wanting, and the existing toes are Nos. 2, 3, and 4. If an animal has only two toes, as the goat, these are Nos. 3 and 4; and if only one, as the

124

125

horse, it is the third or middle toe. Or, to put it more definitely: hoofed animals are divided into two groups, even-toed (artiodactyl) and odd-toed (perissodactyl). The even-toed may have four, as in the hippopotamus; or two, as in the goat. The odd-toed may have three, as in the rhinoceros; or but one, as in the horse. Now, both of these orders came by differentiation, far back in the Eocene Tertiary, from a five-toed plantigrade ancestor. After dropping No. 1 (thumb or great toe) it is not yet decided, so far as number of toes is concerned, whether the resulting four-toed animal shall become artiodactyl or perissodactyl. If the former, then the two side-toes (Nos. 2 and 5) become shortened up, as in the hog; then rudimentary, as in the ox and deer; and finally pass away entirely, as in the goat. If, on the other hand, the four-toed animal is on the line of perissodactyl evolution, it becomes first a three-toed animal by dropping No. 5. Now, the two side-toes (Nos. 2 and 4) shorten up more and more, and the middle toe increases in size, until finally, in the modern horse, only the greatly enlarged middle toe (No. 3) remains. We look with wonder and admiration at the *danseuse* pirouetting on the point of one toe. The horse is performing this feat all the time. Yes, the one toe of a horse has all the three joints like ours. The coffin-bone is the last joint, and the hoof is the nail.

a b c d e f g

Equus: Quaternary and Recent.

Pliohippus: Pliocene.

Protohippus: Lower Pliocene.

Miohippus: Miocene.

Mesohippus: Lower Miocene.

Orohippus: Eocene.

FIG. 25.—Diagram illustrating gradual changes in the horse family. Throughout *a* is fore-foot; *b*, hind-foot; *c*, fore-arm; *d*, shank; *e*, molar on side-view; *f* and *g*, grinding surface of upper and lower molars (after Marsh).

Genesis of the Horse.—Every step of this process on the perissodactyl line may be traced in the history of the genesis of the horse. The beautiful form and structure of this animal were not made at once, but by a slow process of integration of small changes from generation to generation, and from epoch to epoch of the earth's history. The horse (as in fact did all ungulates) came from a five-toed *plantigrade* ancestor, but we are not able to trace the direct line of genesis quite so far. The earliest stage that we can trace with certainty, in this line of descent, is found in the eohippus of Marsh. This

was a small animal, no bigger than a fox, with three toes behind and four serviceable toes in front, with an additional fifth palm-bone (splint), and perhaps a rudimentary fifth toe like a dew-claw. This was in early Eocene times. Then, in later Eocene, came the orohippus, which differs from the last chiefly in the disappearance of the rudimentary fifth toe and splint. (See [Fig. 25.](#)) Next, in the Miocene, came the mesohippus and miohippus. These were larger animals (about the size of a sheep), and had three serviceable toes all around; but in the former the rudiment of a fourth splint in the fore-limb yet remained. Then, in the Miocene, came the protohippus and pliohippus. These were still larger animals, being about the size of an ass. In the former the two side-toes were shortening up and the middle toe becoming larger. In the latter the two side-toes have become splints. Lastly, only in the Quaternary comes the genus *Equus*, or true horse. The size of the animal is become greater, the middle toe stronger, the side-splints smaller; but in the side-splints of the modern horse we have still remaining the evidence of its three-toed ancestor.

128

Similar gradual changes may be traced in the two leg-bones, which have gradually consolidated into one; in the teeth, which have become progressively longer and more complex in structure, and therefore a better grinder; in the position of the heel and wrist, which have become higher above-ground; in the general form, which has become more graceful and agile; and, lastly, in the brain, which has become progressively larger and more complex in its convolutions—to give greater battery-power, to make a more powerful dynamo—to work the improved skeletal machine. See, then, how long it has taken Nature to produce that beautiful finished article we call the horse!

* * * * *

We have taken only limbs as examples of what is true of the whole skeleton. To the superficial observer the bodies of animals of different classes seem to differ fundamentally in plan—to be entirely different machines, made each for its own purposes, at once, out of hand. Extensive comparison, on the contrary, shows them to be the same, although the essential identity is obscured by adaptive modifications. The simplest, in fact the only scientific, explanation of the phenomena of vertebrate structure is the idea of a primal vertebrate, modified more and more through successive generations by the necessities of different modes of life.

129

See, then, in conclusion, the difference between man's mode of working and Nature's. A man having made a steam-engine, and desiring to use it for a different purpose from that for which it was first designed and used, will nearly always be compelled to add new parts not contemplated in the original machine. Nature rarely makes new parts—never, if she can avoid it—but, on the contrary, adapts an old part to the new function. It is as if Nature were not free to use any and every device to accomplish her end, but were conditioned by her own plans of structure; as, indeed, she must be according to the derivation theory. For example: In early Devonian times fishes were the only representatives of the vertebrate type of structure. The vertebrate machine was then a *swimming-machine*. In the course of time, when all was ready and conditions were favorable, reptiles were introduced. Here, then, is a new function—that of locomotion on land. We want a *walking-machine*. Shall we have a new organ for this new function? No: the old swimming-organ is modified so as to adapt it for walking. Time went on, until the middle Jurassic, and birds were introduced. Here is a new and wonderful function, that of flying in the air. We want a *flying-machine*. We know how man would have done this; for we have the result of his imagination in angels of Christian art and griffins of Greek mythology. He would have added wings to already existing parts, and this would have necessitated the alteration of the whole plan of structure, both skeletal and muscular. Nature only modifies the fore-limbs for this new purpose. If we must have wings, we must sacrifice fore-legs. We can not have both without violating the laws of morphology. Finally, ages again passed, and, when time was fully ripe, man was introduced. Now we want some part to perform a new and still more wonderful function. We want a *hand*, the willing and efficient servant of a rational mind. We know, again, how man would have done this, for we have the result in the centaurs of Greek mythology, in which man's chest, and arms, and head are added to the body of a quadruped. But natural laws must not be violated, even for man. If we want hands, we must sacrifice feet. Again, therefore, the fore-limbs are modified for this new and exquisite function. Thus, in the fin of a fish, the fore-paw of a

130

reptile or a mammal, the wing of a bird, and the arm and hand of a man, we have the same part, variously modified for many purposes.

Many other illustrations might be taken from the skeleton and from other systems, especially the muscular and nervous. But in the muscular system the modifications have been so extreme that homology is much more difficult to trace, and therefore requires more extensive knowledge than we yet possess, and more extended comparison than has yet been attempted. It has been traced with some success through mammals, and probably will be through air-breathing vertebrates—i. e., also through birds, reptiles, and amphibians; but to trace it through fishes seems almost hopeless. In the case of the nervous system, and especially of the brain, it is again distinct; but this had better be taken up under another head, viz., proofs from ontogeny, [Chapter VI](#).

131

In the visceral organs homology is very plain, in fact too plain. There is not modification enough in most cases even to obscure it, because function is the same in all animals. These organs do not, therefore, furnish good illustrations of that essential identity in the midst of adaptive modification which constitutes the argument for the derivative origin of structure. It is the organs of *animal life* that show this most perfectly, because it is these that take hold on the environment and are modified by it. There are, however, a few striking illustrations to be found among the visceral organs, especially the blood-system. This, however, had better also be deferred to the chapter on ontogeny.

132

CHAPTER VI.

HOMOLOGIES OF THE ARTICULATE SKELETON.

We have taken the vertebrate skeleton first, only because this department is most familiar. But in reality, the most beautiful illustrations of essential identity of structure in the midst of infinite diversity of adaptive modification for different functions and habits of life, and therefore of common origin from a primal form, are found in the department of articulates. I use the old Cuvierian department *articulata*, rather than the more modern *arthropods*, because the former includes worms also. Now, whether worms should be thus included with arthropods, or deserve a whole department to themselves it matters not for our purposes. It is generally admitted that arthropods probably descended from marine worms. They all have the same general plan of skeletal structure. It will suit my purpose, therefore, to regard worms as the lowest form of jointed animals.

Here, then, we have an entirely different plan of structure—a different style of architecture and different mechanical principles of machinery. Instead of a skeleton within and muscles acting on the outside, we have the skeleton on the outside, and muscles acting from within. Instead of two cavities, a neural and visceral, the skeleton forms but one cavity, in which all organs are inclosed and protected. Instead of finding the nerve-axis on the dorsal aspect of the body, we find it on the ventral aspect.

133

FIG. 26.—Diagram section across an arthropod, showing the inclosing skeleton-ring and a pair of jointed appendages, *n*, nervous center; *v*, viscera; *b*, blood system.

Take any articulate animal, for example, a shrimp, a centipede, or a beetle. Cut it across the body, and look at the end ([Fig. 26](#)). We see a ring of bone (chitin) inclosing all the organs (nervous system *n*, blood system *b*, and visceral system *v*), and a pair of jointed appendages, perhaps legs, on each side. Now imagine these parts repeated in a linear series. The rings repeated make a hollow, jointed tube or barrel, the appendages repeated make a continuous row of appendages on each side. Now this is exactly what we actually find. The whole articulate skeleton is ideally made up of a series of such repeated rings and appendages, modified according to the position in the series, and the uses to which

134

they are put. And then the whole articulate department is made up of such articulate animals again modified according to place in the scale of articulates. The modification in the lower forms is slight, and therefore the identity of the repeated parts is obvious; but as we go up the scale, and the number and complexity of the functions increase, the adaptive modification becomes greater and greater, until finally it so obscures the essential identity, that it requires the most extensive comparison in the taxonomic series and in the ontogenic series, to pick up the intermediate links and establish the fact of common origin. In a word, whether they so originated or not, it is certain that the structure of articulate animals is exactly such as would be the case if all these animals were genetically connected, and came originally from a primal form something like one of the lower crustaceans, or, perhaps, a marine worm.

FIG. 27.—Shrimp (*Palæmonetes vulgaris*).

FIG. 28.—External anatomy of the lobster (after Kingsley).

It will be best to take an example from about the middle of the scale, where the two elements, viz., essential identity and adaptive modification, are somewhat evenly balanced, and both traceable with ease and certainty. Take, then, a cray-fish, a lobster, or a shrimp. This animal ([Fig. 27](#)) has twenty or twenty-one rings and pairs of jointed appendages. The rings are some of them diminished, some of them increased in size. Sometimes several are consolidated; sometimes several are partially or wholly aborted. The appendages are modified in shape and size, according to their position, so as to make them swimming-appendages (swimmerets), walking-appendages (legs), eating-appendages (jaws), and sense-appendages (antennæ). For example, in the abdominal region, or so-called tail, we have seven segments, all being perfect movable rings, each with its pair of jointed appendages, except the last, or *telson*. The appendages of the first ring ([Fig. 28](#), B) are specially modified in the male as organs of copulation (B'). The next four pairs are modified for swimmerets (D') and for use as holders of the eggs in the female. The appendages of the sixth ring (G) are broad and paddle-shaped, and, together with the telson or seventh ring (H), form the powerful terminal swimmer. Going, now, to the cephalothorax: in this either a large number of segments (thirteen or fourteen) are consolidated above to form the upper shell or carapace; or else, as is more probable, two or three of the anterior segments have enlarged and grown backward over, and at the expense of the others, to form this shell. At any rate, it is certain that the carapace is formed of the dorsal portions of a number of segments consolidated

135

137

together. Below, however, the segments are all distinct, and have each its own pair of appendages. For example, going forward in this region, the five next pairs of appendages are greatly enlarged and very strong, and serve the purpose of locomotion. They are *walking-appendages*. The next two or three pairs are smaller and somewhat modified, but not so much as to obscure their essential similarity to legs. Like legs, they are many-jointed, and like legs, too, they have gills attached to them. They are called maxillipeds, or jaw-feet. They are used like hands to gather food and carry it to the mouth. They are *gathering-appendages*. Then follow three or four pairs still more modified, and used for mastication. They are called maxillæ and mandibles. They are *eating-appendages*. Then follow two pairs, long, many-jointed, with the same kind of curious hinge-joints, which we have in the legs, undoubtedly homologous with all the others, but used for an entirely different purpose, and specially modified for that purpose. They are the antennæ. They are delicate organs of touch and of hearing, for the ear is situated in the basal joint of the anterior pair. Last of all, there is still another pair, jointed and movable, on the ends of which are situated the eyes. These last three, therefore, are *sense-appendages*. Some writers make this last pair special organs, not homologous with appendages.

138

139

FIG. 29.—Appendages of a prawn (after Cuvier).

FIG. 30.—Appendages of Nebalia.

For the sake of greater distinctness, we give the whole series of these appendages in one of the higher forms, viz., the prawn (Palemon, [Fig. 29](#), and in one of the lower forms, Nebalia, [Fig. 30](#)).

FIG. 31.—Vibilia, an amphibod crustacean (after Milne Edwards).

That these are really homologous parts is further shown by the fact that in the case of other crustaceans, such as *limulus*, the same appendages, i. e., the appendages of the same body segments, which in the cases before mentioned are used as feet, become swimmers, while the appendages corresponding to jaw-feet become walkers; and even what corresponds to antennæ or sense-appendages, may, as in *branchippus*, become powerful claspers. Finally, in all the lowest crustaceans, the identity is evident, because all the segments and their appendages are much alike in form and function ([Fig. 31](#)).

FIG. 32.—Lithobius forcipatus (after Carpenter).

We have taken examples from near the middle of the articulate scale, because, as already stated, both the essential identity and the adaptive modifications are easily traced. If we go downward in the scale, the structure becomes more and more generalized, and the rings and appendages become more and more alike ([Fig. 31](#)), until in the most generalized forms we have only a series of similar rings, with similar pairs of appendages, except some necessary modifications to form the head and tail. This is well shown in the centiped ([Fig. 32](#)), and still better in marine worms ([Fig. 33](#)). In some marine worms the slight modification to form the head takes place under our very eyes. These often multiply by dividing themselves into two. When they do so, they make a new head and new tail by slight modification of segments and appendages ([Fig. 33](#)).

FIG. 33.—*Syllis prolifera*.

If, on the other hand, we go up the scale, we find adaptive modifications obscuring more and more the simple and obvious identity of parts, until finally the identity can not be recognized without extensive comparison in the taxonomic series and study of embryonic conditions. In crabs—which is a higher form than cray-fish—the tail or abdomen seems to be wanting, but is only very small and bent under the body and thus concealed. In all essential respects the structure is precisely like the cray-fish. In fact, in the embryo, we trace the one form into the other; for the crab is at first a long-tailed crustacean ([Fig. 34](#)).

141

FIG. 34.—Development of *Carcinus mœnas*. A, zoæa stage; B, megalopa stage; C, final state (after Couch).

Insects are the highest form of articulates. In these, therefore, we find the modification is still greater than in crustaceans, though even here the ring-and-appendage structure is plain enough in most cases.

One of the best evidences of high grade among animals is the gathering of the segments into distinct groups, and especially the distinctness of the *head* as one of these groups. In worms and lower crustaceans there is no grouping at all, the skeleton being a continuous series of joints, only slightly modified at the anterior and posterior extremities. In the higher crustacea, and in spiders and scorpions, they are grouped into two regions, viz., cephalo-thorax and abdomen. In insects they are grouped into three very distinct regions—head, thorax, and abdomen. In insects, therefore, we find for the first time the head distinctly separated from the rest of the body. This is an evidence of high grade, because it shows the dominance of head-functions.

143

FIG. 35.—External anatomy of *Caloptenus spretus*, the head and thorax disjointed; up, uropatagium; f, furcula; c, cercus (drawn by J. T. Kingsley).

The insect, such, for example, as a grasshopper, consists of seventeen or eighteen segments ([Fig. 35](#)). Of these, four belong to the head, three to the thorax, and about ten to the abdomen. Those of the abdomen are all separated and movable; those of the thorax and head are more or less consolidated. The appendages of the head-segments become antennæ and jaw-parts, i. e., mandibles—maxillæ and labium; the appendages of the thorac-segments become legs (the wings are not homologous with appendages), while those of the abdomen are aborted. The steps of the gradual consolidation on the one hand, and the abortion on the other, may be traced in the embryo or larva—i. e., in the caterpillar or the grub of a bee or a beetle. In the caterpillar, for example, there is no grouping into three regions, there is no consolidation, and all the segments have appendages. Again, the almost infinite variety in the mouth-parts among insects, brought about by adaptive modifications for biting, for piercing, and for sucking, and yet the essential identity of all to the more simple and generalized structure of the grasshopper, is an admirable illustration of the same principle. But to dwell upon these minor points would carry us too far.

Illustration of the Law of Differentiation.—We have here, in the modifications of segments and appendages of articulates, an admirable illustration of the most fundamental law of evolution, viz., the

law of differentiation. As we have already seen ([page 21](#)), perhaps the most beautiful and certainly the most fundamental illustration of this law is found in the development of cell-structure. Commencing in the lowest animals, and in the earliest embryonic stages of the higher animals, from a condition in which all are alike, the *cells* as we go upward quickly diverge into different forms to produce different tissues and perform different functions. Here, then, we have a perfect example of essential identity and adaptive modification. It is the very best type of differentiation. So also skeletal *segments*, commencing, in the lowest articulates and in earliest embryonic stages of the higher, all alike, as we go upward in either series, begin immediately to diverge in various directions (divergent variation), taking different forms to subserve different uses. Here, again, therefore, is an illustration of the law of differentiation. Lastly, in the articulate department, commencing with the lowest forms and earliest embryonic conditions, and we may add earliest geological times, and going up either series from generalized forms very much alike, the *individuals* are gradually differentiated into many special forms, in order to adapt them to the diversified modes of life actually found in nature. Thus cells, segments, individuals, are all alike affected by this most fundamental law.

We have taken our illustrations from only the two departments of vertebrata and articulata, because these are the most familiar to the reader, and also have been most carefully studied. We have shown that the general structure of all vertebrates is precisely what it would be if they all had come from one primal vertebrate form, and that of all articulates what it would be if all had come from one primal articulate form. The only *natural* explanation, and, therefore, the only scientific explanation of this, is that *they were really thus derived*. The same kind of evidence may be drawn from the study of other departments, but to pursue the subject any further in this direction would carry us beyond the limits which we have assigned. We desire only to explain the nature, not to give all, of the evidence. The examples given will be sufficient for the purposes of illustration. The whole proof is nothing less than the whole science of comparative anatomy. 145

Vertebrates, then, were derived from a primal vertebrate, articulates from a primal articulate, and so for other departments. But whence were these *primals* derived? Are there any intermediate links between, any deeply concealed common plan of structure underlying these primary groups, showing a common origin? It must be confessed that, in their *mature* condition, there seems to be but little evidence of such. These primary groups seem to be built on different plans, to be fundamentally of different styles of architecture. Therefore Darwin, in the true spirit of inductive caution—that true scientific spirit which keeps strictly within the limits of evidence—commences with four or five distinct primal kinds, from which by divergent variation all animals were descended. Nevertheless, the truly scientific biologist must ever strongly incline to believe that these also came from some *primal animal*, and even that both animals and plants were derived from some primal form of *living thing*; that as, in the taxonomic series, the animal and vegetal kingdoms in their lowest forms merge undistinguishably into one another; as in the ontogenic series the animal and plant germ are one, so also in the phylogenic series the earliest organisms were simply living things, but not distinctively animal nor vegetal. Science, therefore, whose mission is to trace origins as far back as possible, must ever strive to find connecting links between the primary groups. Some such have been supposed to have been discovered. Some find the origin of vertebrates among the molluscoids (ascidians); some find the origins of both vertebrates and articulates among marine worms (annelids). This point is still too doubtful to be dwelt upon here. It may be that we seek in vain for such connecting links among existing forms. It may well be that the point of separation of these great primary groups (unless we except vertebrates) was far lower even than these low forms. Both phylogeny and ontogeny seem to indicate this. In the earliest fauna known, the primordial (for if there was life in the archæan it was not yet differentiated into a fauna), all the great departments, except the vertebrates, seem to have been represented. In embryonic development, too, the point of connection or even of similarity, between the great departments, is found, as we shall see hereafter, only in the earliest stages—i. e., lower down than any but the lowest existing forms, viz., the protozoa. 146

147

CHAPTER VII.

PROOFS FROM EMBRYOLOGY, OR COMPARISON IN THE ONTOGENIC SERIES.

It is a curious and most significant fact that the successive stages of the development of the *individual* in the higher forms of any group (ontogenic series) resemble the stages of increasing complexity of differentiated structure in ascending the animal scale in that group (taxonomic series), and especially the forms and structure of animals of that group in successive geological epochs (phylogenic series). In other words, the individual higher animal in embryonic development passes through temporary stages, which are similar in many respects to permanent or mature conditions in some of the lower forms in the same group. To give one example for the sake of clearness: The frog, in its early stages of embryonic development, is essentially a fish, and if it stopped at this stage would be so called and classed. But it does not stop; for this is a temporary stage, not a permanent condition. It passes through the fish stage and through several other temporary stages, which we shall explain hereafter, and onward to the highest condition attained by amphibians. Now, if we could trace perfectly the successive forms of amphibians, back through the geological epochs to their origin in the Carboniferous, the resemblance of this series to the stages of the development of a frog would doubtless be still closer. Surely this fact, if it be a fact, is wholly inexplicable except by the theory of derivation or evolution. The embryo of a higher animal of any group passes *now* through stages represented by lower forms, because in its evolution (phylogeny) its ancestors *did actually have these forms*. From this point of view the ontogenic series (individual history) is a brief recapitulation, as it were, from memory, of the main points of the philogenic series, or family history. We say brief recapitulation of the *main* points, because many minor points are dropped out. Even some main points of the earliest stages of the family history may be dropped out of this sort of inherited memory.

149

This resemblance between the three series must not, however, be exaggerated. Not only are many steps of phylogeny, especially in its early stages, dropped out in the ontogeny, but, of course, many adaptive modifications for the peculiar conditions of embryonic life are added. But it is remarkable how even these—for example the umbilical cord and placenta of the mammalian embryo—are often only modifications of egg-organs of lower animals, and not wholly new additions. It is the similarity in spite of adaptive modifications that shows the family history.

We will now illustrate by a few striking examples.

We can not do better than to take, again, as our first example, the development of tailless amphibians, and dwell a little more upon it:

150

1. Ontogeny of Tailless Amphibians.—It is well known that the embryo or larva of a frog or toad, when first hatched, is a legless, tail-swimming, water-breathing, gill-breathing animal. It is essentially a fish, and would be so classed if it remained in this condition. The fish retains permanently this form, but the frog passes on. Next, it forms first one pair and then another pair of legs; and meanwhile it begins to breathe also by lungs. At this stage it breathes equally by lungs and by gills; i. e., both air and water. Now, the lower forms of amphibians, such as siredon, menobranchus, siren, etc., retain permanently this form, and are therefore called *perennibranchs*, but the frog still passes on. Then the gills gradually dry up as the lungs develop, and they now breathe wholly by lungs, but still retain the tail. Now this is the permanent, mature condition of many amphibians, such as the triton, the salamander, etc., which are therefore called *caducibranchs*, but the frog still passes on. Finally, it loses the tail, or rather its tail is absorbed and its material used in further development, and it becomes a perfect frog, the highest order (*anoura*) of this class.

Thus, then, in ontogeny the fish goes no further than the fish stages. The perennibranch passes through the fish stage to the perennibranch amphibian. The caducibranch takes first the fish-form, then the perennibranch-form, and finally the caducibranch-form, but goes no further. Last, the anoura takes first the fish-form, then that of the perennibranch, then that of the caducibranch, and finally becomes anoura. This is shown in the diagram, which must be read upward, line by line.

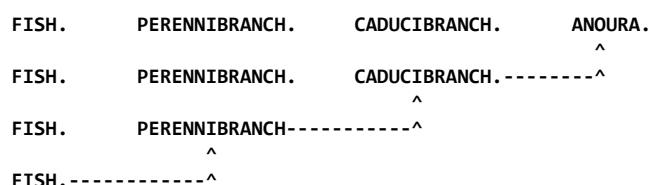


Diagram showing the stages of development of amphibians. (To be read upward.)

Now, this is undoubtedly the order of succession of forms in geological times—i. e., in the phylogenic series. This series is indicated by the arrows in the diagram. Fishes first appeared in the Devonian and Upper Silurian in very reptilian or rather amphibian forms. Then in the Carboniferous, fishes still continuing, there appeared the lowest—i. e., most fish-like—forms of amphibians. *These were undoubtedly perennibranchs*. In the Permian and Triassic higher forms appeared, which were certainly caducibranch. Finally, only in the Tertiary, so far as we yet know, do the highest form (anoura) appear. The general similarity of the three series is complete. If we read the diagram horizontally, we have the ontogenic series; if diagonally with the arrows, we have both the taxonomic and the phylogenic series.

2. Aortic Arches.—But some will, perhaps, say that these stages in the ontogeny are only examples of adaptive modifications—like modifications for like conditions of life—and had better be accounted for in this way, without reference to family history. We will, therefore, take another example, which can not be thus accounted for—an example in which there is no possible use *now* for the peculiar form or structure which we find. For this purpose we take the case of the *course of circulation in vertebrates*.

FIG. 36.—Showing heart and outgoing blood-vessels of a lizard (after Owen). The arrows show the course of the blood.

FIG. 37.—A, heart and gill-arches of a fish; B, one arch, with fringe (after Owen); H, the heart.

If one examines the large vessels *going out* from the heart of a lizard, he will find *six aortic arches*—i. e., three on each side. These all unite below to form the one descending abdominal aorta. This is shown in the accompanying figure ([Fig. 36](#)), in which *a a' a''* and *b b' b''* are the six arches. Now, there is no conceivable use in having so many aortic arches. We know this, because there is but one in birds

and mammals, and the circulation is as effective, nay, much more effective in these than in reptiles. The explanation of this anomaly is revealed at once as soon as we examine the circulation of a *fish*, which is shown in the accompanying figure ([Fig. 37](#)). The multiplication of the aortic arches is here, of course, necessary, for they are the *gill-arches*. The whole of the blood passes through these arches, to be aërated in the gill-fringes. The use of this peculiar structure is here obvious enough. If a lizard were ever a fish, and afterward turned into a lizard, changing its gill-respiration for lung-respiration, then, of course, the useless gill-arches would remain to tell the story. Now, although a lizard never was a fish, in its *individual* history or ontogeny, it was a fish in its family history or phylogeny, and therefore it yet retains, by heredity, this curious and *useless* structure as evidence of its ancestry.

153

FIG. 38.

FIG. 39.

FIGS. 38, 39.—Diagrams showing the change of the course of blood in the development of a frog. 38. The tadpole stage. 39. The mature condition. H, heart; G G' G'', external gills; g g' g'', internal gills; c c, connecting branches in the tadpole; p p, pulmonary branches.

That this is the true explanation is demonstrated by the fact that in amphibians this very change actually takes place before our eyes in the *individual history*. We have already seen that the individual frog, in its tadpole state, is a gill-breather. It has therefore its gill-arches ([Fig. 38](#)), three on each side,

154

155

like a fish, and for the same reason, viz., the aëration of the blood. But when its gills dry up and lung-respiration is established, its now useless gill-arches still remain as aortic arches, to attest their previous condition ([Fig. 39](#)). Now, the lizard undoubtedly came from an air-breathing, tailed amphibian, and therefore inherited this form of arterial distribution. In both lizard and amphibian the ultimate cause is an origin from fishes, in which such arches are obviously necessary. The diagrams, [Figs. 38](#) and [39](#), are illustrations somewhat idealized, showing the manner in which the change actually takes place in air-breathing amphibians. [Fig. 38](#) represents the tadpole stage, and [Fig. 39](#) the mature condition. In the former the gills are mostly external, $G\ G'$, etc., but also internal, $g\ g'$, as in the fish. Observe in this condition the small connecting vessels, $c\ c'$. When the external gills dry up, these are enlarged, and the whole of the blood passes through them, as shown in [Fig. 39](#). It is seen, also, in [Fig. 38](#), that a small branch, p , goes from the lower gill-arches to the yet rudimentary lung, l . When the gill-fringes have disappeared, the whole of the blood of the lower arch goes through the now enlarged pulmonary branch to the lungs, L , now in full activity, and the remainder of this arch disappears, as shown by the dotted lines in [Fig. 39](#).

The change which actually took place in the family history of the lizard probably differed from the above only in being more simple, the gills being only internal like the fish. The external gills complicate the process a little in the case of the frog, but the principle is precisely the same.

156

As already explained ([pages 82–85](#)), the large gap between fishes and reptiles, as regards mode of respiration, is completely filled both in the taxonomic series—i. e., in ganoids, dipnoi, and the mature condition of the different orders of amphibians—and in the ontogeny of the higher amphibians. Now, we add that the same is true of the arterial distribution. We have just traced the change in the ontogeny of the frog, but the steps of the same change are traceable in passing from the typical fish (teleosts), through dipnoi and amphibians to reptiles. Thus, again, the phylogeny, the taxonomy, and the ontogeny, are in complete accord.

But the argument for evolution does not stop here. If birds and mammals have come from reptiles, and therefore from fishes, we may expect to find some evidences of the same kind still lingering in the great arteries. And such we do find. It is a most curious and significant fact that, in the early embryonic condition of birds and mammals, including man himself, we find on each side of the neck several gill-slits, each with its gill-arch, and therefore *several aortic arches on each side*, precisely similar to what we have already described. These arches are subsequently, some of them, obliterated; some modified to form the one aortic arch, and some of them still more modified to form the other great arteries coming from the heart to supply the head and forelimbs.

157

FIG. 40.—Diagram of mammalian heart. *a*, aorta; *p*, pulmonary artery; *scs'c'*, subclavium on each side; *cc'*, carotids on each side.

FIG. 41.—Ideal diagram representing the primitive aortic arches (after Rathke).

This is so beautiful and convincing an example, and one so generally unfamiliar, to even intelligent persons, not especially acquainted with biology, that it is best to explain it more fully. In [Fig. 40](#) we give a mammalian heart and outgoing vessels, very slightly modified, so as to suggest the process of change. In [Fig. 41](#) we give an ideal diagram representing the primitive aortic arches as they exist in the embryo of mammals, birds, and reptiles. It represents, also, substantially, the arches as they exist in the *mature* condition in the most reptilian fishes (dipnoi) and in some sharks, except that in these the arches are of course furnished with gill-fringes. We will use this figure, therefore, to represent both the embryonic condition of air-breathing vertebrates and the mature condition of some fishes. The place of the heart is indicated by the dotted circle. [Fig. 36](#), on [page 134](#), shows what these arches become in reptiles (lizard). It is seen that the two upper arches on each side are obliterated, as indeed they already are in some teleost fishes. [Fig. 42](#) shows what they become in birds. The two upper arches are, of course, obliterated. The others are all modified, each in a manner which may be readily understood by comparison with [Fig. 41](#). Finally, [Fig. 43](#) shows what they become in mammals and in man. In the bird ([Fig. 42](#)) the first pair of arches become the two pulmonary arteries as they do also in the lizard. The second pair become on the right side (left of the diagram) the aortic arch, on the left side (right of the diagram) the left subclavian, *s'c'* (the right subclavian, *sc*, is a branch of the aortic arch). The third pair become carotids, *cc*, while the fourth and fifth, as already said, are aborted. In the mammal ([Fig. 43](#)), on the left side (right of the diagram) the first arch becomes the pulmonary artery, *p*. In the foetus the continuation of this arch forms the ductus arteriosus, which is afterward obliterated, as shown in the dotted line. The second arch becomes the aortic arch, the third the left exterior carotid. On the right side (left of the diagram) the first arch becomes aborted; the second, the right subclavian, *sc* (the *left* subclavian, *s'c'*, is a branch of the aortic arch); and the third, the right carotid. Nos. 4 and 5, on both sides, as usual, are aborted.

158

159

FIG. 42.—Modified for bird.

FIG. 43.—Modified for mammal.

**FIG. 44.—
Lancelet
(Amphioxus
lanceolatus).
Magnified
two and
one-half
times.**

See, then, the gradual process of change through the whole vertebrate department. In the lowest of all vertebrates, if vertebrate it may be called (for what corresponds to its backbone is an unjointed, fibrous cord), the amphioxus or lancelet ([Fig. 44](#)), there are about forty gill-arches on each side. As we rise in the scale of fishes these are reduced in number. In the lamprey, there are seven; in the sharks, usually five; in ordinary fishes (teleosts), there are four or sometimes only three on each side, the others being aborted. Thus far the change is only by diminution of number in accordance with a law universal in biology, that decrease in the number of identical organs is evidence of advance in the grade of organization, provided that it be associated with more perfect structure of the organ. The further change is one of adaptive modification. In some reptiles (lizard) the three gill-arches on each side all retain the form of aortic arches; in some reptiles only two retain this form. In birds and

mammals only one arch is retained, in the form of aortic arch, the others being modified to form the great outgoing vessels of the heart, or else aborted. It may be well to observe that in birds the one aortic arch turns to the right, while in mammals it turns to the left. This is positive evidence that mammals could not have come from birds, nor *vice versa*. They both came from reptiles, and, of the many reptilian arches, a right one was retained by the bird branch, and a left one by the mammalian. 161

In all the figures illustrating this subject, we have left out the great *incoming* vessels or veins, because we are not here concerned with them, they not being transformed gill-arches.

Last of all, it may be well to stop a moment to show the cogency of this evidence. If it were a question of the origin of some structure not only useful (for all structures selected by Nature must be useful) but the *best imaginable*, like the eye or the ear, for example; then, if *we examined only the highest form or the finished article*, there are two ways in which it is possible to explain the adaptive structure. We may either suppose that it was made at once out of hand, by some intelligent contriver; or else that it was slowly made by a process of evolution, becoming more and more perfect by a selection of only the most perfect from generation to generation. But in the case of the six aortic arches of the lizard, we are shut up to the one explanation only, viz., by slow process of evolution. One arch is all that is necessary, as is plainly shown by the use of only one in the more perfect circulation of birds and mammals. If the thing were done out of hand, unconditioned by the previous structure in fishes, to have made six was surely but a bungling piece of work. 162

FIG. 45.—Fish-brain. A, side view; B, top view.

FIG. 46.—Reptile-brain. A, side view; B, top view.

FIG. 47.—Bird-brain. A, side view; B, top view.

FIG. 48.—Mammal-brain. A, top view; B, side view.

FIG. 49.—Man's brain. A, side view; B, top view.

3. Vertebrate Brain.—Another excellent example is the structure of the vertebrate brain. The brain of an average fish is represented in [Fig. 45](#). It consists of four or five swellings, or ganglia, strung along, one beyond another. Commencing behind, these are, first, the medulla, *m*; then the cerebellum, *cb*; then the optic lobes, *ol*; then the cerebrum and thalamus combined, *cr*; and last, the olfactive lobes, *of*. Of these, it will be observed, the optic lobe is the largest in the brain of the fish ([Fig. 45](#)). In the brain of the reptile ([Fig. 46](#)) we have the same serial arrangement, of the same parts, only that the cerebrum has now become the dominant part instead of the optic lobes. In the average bird ([Fig. 47](#)) the cerebrum has grown so large that it extends backward, and partly covers the optic lobes. In the lower mammals (marsupials), the brain is much the same in this respect, as in birds—i. e., the cerebrum only partly covers the optic lobes, so that, looked at from above, the whole series of ganglia are still visible. But in the average mammal ([Fig. 48](#)) the cerebrum is so enlarged that it covers entirely the optic lobes and encroaches on the cerebellum behind and the olfactive lobes in front. In some monkeys, indeed, the cerebellum is nearly or even quite covered. Finally, in man ([Fig. 49](#)), the cerebrum has grown so enormously that it covers every other part and completely conceals them from view when the brain is looked at from above. In front it not only covers but has grown far beyond the olfactive lobes; behind it extends beyond and overhangs the cerebellum; on the sides it overhangs and covers all. Looked at from above, nothing is seen but this great ganglion. The ideal section ([Fig. 50](#)) represents all these stages diagrammatically in one figure. After what has been said, the figure will be readily understood.

163

164

165

FIG. 50.—Ideal section showing all the above stages.

**FIG. 51.—Sub-fish Stage. *th*,
thalamus; *ol*, optic lobe; *m*, medulla.**

**FIG. 52.—Fish-stage. *of*, olfactory lobe; *cr*,
cerebrum; *th*, thalamus; *ol*, optic lobe;
cb, cerebellum; *m*, medulla.**

FIG. 53.—Reptile-stage.

Now, it is a most remarkable fact that substantially these same stages, which are permanent conditions in the taxonomic series, are passed through as transient stages in the embryonic development of the human brain, and in the order given above. The very early condition of the human brain is represented in [Fig. 51](#). It is evidently nothing more than the intercranial continuation of the spinal cord, enlarged a little into three swellings or ganglia. These are the early representatives of the medulla, the optic lobes, and the thalamus; which last may be regarded as the basal and most fundamental part of the cerebrum. This stage may be regarded as lower than that of the ordinary fish. I have called it, therefore, the *sub-fish stage*. The cerebellum is a subsequent outgrowth from the medulla, as is the cerebrum and olfactive lobes from the thalamus. [Fig. 52](#) may be said, therefore, to represent fairly the fish-stage. Henceforward the principal growth is in the cerebrum and cerebellum, both of which are subsequent outgrowths of the original simple ganglia, the medulla, and the thalamus. The cerebrum especially increases steadily in relative size, first becoming larger than but not covering the optic lobes ([Fig. 53](#)). This represents the reptilian stage. Next, by further growth, it covers partly the optic lobes ([Fig. 54](#)). This may be called the bird-stage. Then it covers wholly the optic lobes, and encroaches on the cerebellum behind and olfactive lobes in front ([Fig. 55](#)). This is the mammalian stage. Finally, it covers and overhangs all, and thus assumes the human stage ([Fig. 56](#)).

166

167

FIG. 54.—Bird-stage. *of*, olfactive lobe; *cr*, cerebrum; *th*, thalamus; *ol*, optic lobe; *cb*, cerebellum; *m*, medulla.

FIG. 55.—Mammalian stage.**FIG. 56.—Human stage.**

We have spoken thus far only of relative *size*; but progressive changes take place also in complexity of structure—i. e., in the depth and number of convolutions of the cerebrum and cerebellum. The cerebrums of fish, of reptile, bird, and lower mammals are smooth. About the middle of the mammalian series it begins to be convoluted. These convolutions become deeper and more numerous as we go upward in the scale, until they reach the highest degree in the human brain. The object of these inequalities is to increase the surface of gray matter—i. e., the extent of the force-generating as compared with the force-transmitting part of the brain, or battery as compared with conducting-wire. Now, in embryonic development the human brain passes also through these stages of increasing complexity of organization. Here also the ontogenic is similar to the taxonomic series.

168

Now, why should this peculiar order be observed in the building of the individual brain? We find the answer, the only conceivable scientific answer to this question, in the fact that *this is the order of the building of the vertebrate brain by evolution* throughout geological history. We have already seen that fishes were the only vertebrates living in the Devonian times. The first form of brain, therefore, was that characteristic of that class. Then reptiles were introduced; then birds and marsupials; then true mammals; and, lastly, man. The different styles of brains characteristic of these classes were, therefore, successively made by evolution from earlier and simpler forms. In phylogeny this order was observed because these successive forms were necessary for perfect adaptation to the environment at each step. In taxonomy we find the same order, because, as already explained ([page 11](#)), every stage of

advance in phylogeny is still represented in existing forms. In ontogeny we have still the same order, because ancestral characteristics are inherited, and family history recapitulated in the individual history.

**FIG. 57.—A, brain of extinct
Ichthyornis; B, modern tern.**

FIG. 58.—A, brain of Eocene dinoceras; B, Miocene brontothere; C, modern horse.

But not only is this order found in the evolution of the whole vertebrate department, but something of the same kind is found also in the evolution of *each class*. The earliest reptiles, the earliest birds, and the earliest mammals had smaller and less perfectly organized brains than their nearest congeners of the present day. This is shown in the accompanying figures ([Figs. 57](#) and [58](#)). To carry out one example more perfectly: In the history of the horse family, in connection with the changes of skeletal structure already described ([page 108](#)), we have also corresponding changes in the size and structure of the brain; *pari passu* with the improvement of the mechanism we have also increased engine-power and increased muscular energy and therefore increased activity and grace. The brain of a modern horse, though not very large, is remarkable for the complexity of its convolutions. The great energy, activity, and nervous excitability of the horse are the result of this structure.

169

Cephalization.—Thus, in going up the phylogenic, the taxonomic, or the ontogenic series, we find a gradual process of development headward, brainward, cerebrumward; or, more generally, we might say that in all organic evolution we find an increasing dominance of the higher over the lower, and of the highest over all. For example, in the lowest plane of either series we find first the different systems imperfectly or not at all differentiated. Then, as differentiation of these progress, we find an increased dominance of the highest system—the *nervous system*; then in the nervous system, the increasing dominance of its highest part—the *brain*; then in the brain the increasing dominance of its

171

highest ganglion—the *cerebrum*; and, lastly, in the cerebrum the increasing dominance of its highest substance—the exterior gray matter—as shown by the increasing number and depth of the convolutions. This whole process may be called *cephalization*.

Shall the process stop here? When evolution is transferred from the animal to the human plane, from the physiological to the psychical, from the involuntary and necessary to the voluntary and free, shall not the same law hold good? Yes! all social evolution, all culture, all education, whether of the race or the individual, must follow the same law. All *psychical advance is a cephalization*—i. e., an increasing dominance of the higher over the lower and of the highest over all; of the mind over the body, and in the mind of the higher faculties over the lower; and, finally, the subordination of the whole to the highest moral purpose.

172

FIG. 59.—Homocercal tail-fin.
A, form; B, structure.

FIG. 60.—Heterocercal or vertebrated tail-fin.
A, form; B, structure.

4. Fish-Tails.—Still another and last example: It has long been noticed that there are among fishes two styles of tail-fins. These are the even-lobed, or homocercal ([Fig. 59](#)), and the uneven-lobed, or heterocercal ([Fig. 60](#)). The one is characteristic of ordinary fishes (teleosts), the other of sharks and some other orders. In *structure* the difference is even more fundamental than in *form*. In the former style the backbone stops abruptly in a series of short, enlarged joints, and thence sends off rays to form

the tail-fin ([Fig. 59](#), B); in the latter the backbone runs through the fin to its very point, growing slenderer by degrees, and giving off rays above and below from each joint, but the rays on the lower side are much longer ([Fig. 60](#), B). This style of fin is, therefore, *vertebrated*, the other *non-vertebrated*. [Figs. 59](#) and [60](#) show these two styles in form and structure. But there is still another style found only in the lowest and most generalized forms of fishes. In these the tail-fin is vertebrated and yet symmetrical. This style is shown in [Fig. 61](#), A and B.

FIG. 61.—Vertebrated but symmetrical fin. A, form; B, structure.

Now, in the development of a teleost fish ([Fig. 58](#)), as has been shown by Alexander Agassiz,²⁴ the tail-fin is first like [Fig. 61](#); then becomes heterocercal, like [Fig. 60](#); and, finally, becomes homocercal like [Fig. 59](#). Why so? Not because there is any special advantage in this succession of forms; for the changes take place either in the egg or else in very early embryonic states. The answer is found in the fact that *this is the order of change in the phylogenic series*. The earliest fish-tails were either like [Fig. 61](#) or [Fig. 60](#); never like [Fig. 59](#). The earliest of all were almost certainly like [Fig. 61](#); then they became like [Fig. 60](#); and, finally, only much later in geological history (Jurassic or Cretaceous), they became like [Fig. 59](#). This order of change is still retained in the embryonic development of the last introduced and most specialized order of existing fishes. The family history is repeated in the individual history.

FIG. 62.—Tail of the Archæopteryx.

**FIG. 63.—Tail of a
modern bird.**

Similar changes have taken place in the form and structure of birds' tails. The earliest bird known—the Jurassic Archæopteryx—had a long reptilian tail of twenty-one joints, each joint bearing a feather on each side, right and left (Fig. 62). In the typical modern bird, on the contrary, the tail-joints are diminished in number, shortened up, and enlarged, and give out long feathers, fan-like, to form the so-called tail (Fig. 63). The Archæopteryx' tail is *vertebrated*, the typical bird's *non-vertebrated*. This shortening up of the tail did not take place at once, but gradually. The Cretaceous birds, intermediate in time, had tails intermediate in structure. The Hesperornis of Marsh had twelve joints. At first—in Jurassic—the tail is fully a half of the whole vertebral column. It then gradually shortens up until it becomes the aborted organ of typical modern birds. Now, in embryonic development, the tail of the modern typical bird *passes through all these stages*. At first the tail is nearly one half the whole vertebral column; then, as development goes on, while the rest of the body grows, the growth of the tail stops, and thus finally becomes the aborted organ we now find. The ontogeny still passes through the stages of the phylogeny. The same is true of all tailless animals. The frog is tailed in the larval condition, because its ancestors were tailed amphibians. Even man himself is endowed with a much more considerable tail, viz., eight or nine joints, in his early embryonic condition.²⁵

175

We have taken all our examples from vertebrates, but quite as many and as good examples might be found among articulates. Insects, in the larval state, are worm-like in form. Hence it is probable that the earliest progenitors of this class were worm-like. Again, some insects have aquatic larvæ. The progenitors of these—in fact, of all insects—were probably aquatic. Crabs, in a larval condition, are long-tailed, and we know that the long-tailed crustaceans (Macrourans) preceded the short-tailed (Brachyurans). Water-breathing animals preceded air-breathers; the same is true in the ontogeny of the frog, of many insects, and, we might add, even of mammals. For the breathing of the *fœtus in utero* is essentially by exposure of fœtal blood to the oxygenated blood of the mother in a sort of *gill-fringes* (placental tufts). But why should we multiply examples? The whole of embryology, in every department, is made up of examples of the same law.

176

Illustration of the Differentiation of the Whole Animal Kingdom.—Finally, the law of differentiation in the evolution of the whole animal kingdom may be well illustrated by means of the different directions taken in the development of the eggs of all the various kinds of animals. Suppose, then, we have one thousand eggs, representing all the different departments, classes, orders, families, etc., of animals. Many of these may doubtless be identified by form or size, or some other superficial character, as the eggs of this or that animal, *but structurally they are all alike*. At first, i. e., as germ-cells, they all represent the *earliest condition* of life on the earth, and the *lowest forms* of life now. If we now watch their development, we find that some remain in this first condition without further change. These we set aside. They are *Protozoa*. The remainder continue to develop, but at first it would be impossible to say to which of the several departments or primary groups they each belonged.

177

Then, by cell-multiplication, the original single cell becomes a cell-aggregate. It may be compared now to a compound protozoan, such as Foraminifera. The cell-aggregate then differentiates into layers, and forms, in fact, a two-layered sac called a gastrula. This is the structure of some of the lowest cœlenterates, such as the hydra. Thus far all seem to go together. But now, for the first time, the primary groups are declared. If it be a vertebrate, for example, the most fundamental characters—the cerebro-spinal axis, the vertebral column, and the double cavity, neural and visceral, are outlined. Suppose, now, we set aside all other departments, and fix our attention on the vertebrates. At first we could not tell which were mammals, birds, reptiles, or fishes; but after a while the classes are declared. We now set aside all other classes and watch the mammals. After a while the order declares itself. We select the ungulates. Then the family is declared, say the *Equidæ*; then the genus, *Equus*; and, lastly, the species, *Caballus*.²⁶

The same would be true if we followed any other line of development, whether in vertebrates or in any other department. Observe, then, that, in following any one line as we have done, there is an increasing specialization, and, if we followed all the lines, an increasing differentiation, like the branching and rebranching of a tree. Now, this is the type and illustration of what took place in the development of the animal kingdom. We conclude that the animal kingdom appeared first as Protozoa, then as living cell-aggregates or compound protozoans, then as gastrula or two-layered sacs with oral opening. Then the great primary departments, unless we except the vertebrates, commenced to separate. This took place before the primordial period; for in the primordial fauna we have all the departments, except vertebrates, already declared. This completely explains why it is that we are able to trace homology only within the limits of each primary group.

But the question has doubtless already occurred to the thoughtful reader, “Why should the steps of the phylogeny be repeated in the ontogeny?” The general answer is doubtless to be found in the law of heredity—that wonderful law, so characteristic of living things. We have compared it to a brief recapitulation from memory—the minor points, especially if they be also early, dropping out. But can we not explain it further? It is probable that we find a more special explanation in “*the law of acceleration*,” first brought forward by Prof. Cope. By the law of heredity each generation repeats the form and structure of the previous, and in the order in which they successively appeared. But there is a tendency for each successively-appearing character to appear a little earlier in each successive generation; and by this means time is left over for the introduction of still higher *new* characters. Thus, characters which were once adult are pushed back to the young, and then still back to the embryo, and thus place and time are made for each generation to push on still higher. The law of acceleration is a sort of young-Americanism in the animal kingdom. If our boys acquire knowledge and character similar to that of adults of a few generations back, they will have time while still young and plastic to press forward to still higher planes.

Proofs from Rudimentary and Useless Organs.—These have to a large extent been anticipated under previous heads. The tails of birds and the gill-arches of reptiles are rudimentary. The finger-bones of a whale’s paddle or a turtle’s flipper may be regarded as useless, at least so far as the exact number of constituent pieces is concerned; for an extended surface, without visible joints or separate fingers, is all that is seen, and apparently all that is required. The splint-bones of a horse’s foot or the dew-claws of a dog’s foot are certainly useless. We have already, in speaking of modifications of structure and of embryonic conditions, given many examples of this kind, but it may be well to add some striking examples with this special point in view.

If different orders of existing mammals were indeed made by gradual modification of some generalized primal form, then it is evident that these useless remnants of once useful parts would be most common in the most highly modified forms. Now, of all mammals, the whales are perhaps the most modified or changed from the original mammalian form—so much modified, in fact, that the popular eye scarcely recognizes them as mammals at all. Here, then, we might expect, and do indeed find, many examples:

1. The baleen whales have no teeth, and no use for them. They have instead a wonderful armature of fringed whalebone plates (baleen), by means of which they gather their food.²⁷ Yet the embryo of the whale has a full set of rudimentary teeth deeply buried in the jawbone, and formed in the usual

way characteristic of mammalian teeth—i. e., by an infolding of the epithelial surface of the gum—*but the teeth are never cut*; in fact, they reach their highest development in mid-embryonic life, and are again absorbed. Why, then, this waste of developmental energy? Why should teeth be formed only to be reabsorbed without being cut? The only conceivable answer is, because the ancestors of the whale, before the family of whales was fairly established, had teeth which were gradually, from generation to generation, aborted, because no longer used, the baleen plates having taken their place. If whales were made at once out of hand as we now see them, is it conceivable that these useless teeth would have been given them?

2. Again, many whales have rudimentary pelvic bones, but no hind-limbs. Why should there be pelvic bones, when the sole object of these bones is to act as a basis for hind-limbs? In some whales, for example the right whale, there are also rudiments of hind-legs, but these are buried beneath the skin and flesh, and therefore, of course, wholly useless. The only explanation of these facts is that the ancestors of all the whales before they had become whales were quadrupeds, which afterward took to the water, and little by little the hind-legs, for want of use, dwindled away to the useless remnants which we now find.

181

3. Again, whales seem to be hairless, yet rudimentary hairs are found in the skin. Their organs of smell are rudimentary, but made on the pattern of those of mammals, not of fishes—i. e., they are air-smelling, not water-smelling organs. From all these, as well as many other facts, it is evident that the whales descended in early Tertiary times from some marsh-loving, powerful-tailed, short-legged, scant-haired quadruped by modifications gradually induced by increasing aquatic habits.

Examples of such rudimentary organs might be multiplied without limit. As might be expected, some are found even in man. Such, for example, are the muscles for moving the ear, necessary in animals but useless in man, and therefore rudimentary. Similarly useless in man are the scalp-muscle, used by animals to erect the crest or bristles on the head, and the skin-muscle of the neck and chest, used by animals for shaking the skin of those parts. Most persons have lost the power of using these. For my part I can use them all—ear-muscles, scalp-muscle, skin-muscle—but they serve no useful purpose.

182

Again, and finally, in man and many mammals we find a slender, worm-like appendage about three inches long, attached to the cæcum of the large intestine. Anatomists and physiologists, under the influence of that philosophy which maintains that every part of the fearfully and wonderfully made human frame was *directly* contrived to subserve some useful purpose, have puzzled themselves to find the use of this. It probably has no use; on the contrary, it is a continual source of danger. If the human body had been made at once out of hand, it would not have been there. How came it, then? It is the rudimentary remnant of an organ—a greatly enlarged cæcum—which has served, and in some mammals still serves, a useful purpose. All these cases are survivals; they are organs which, like many customs in society, have outlived their usefulness, but still continue by heredity.

But why multiply examples? All along the track of evolution organs become useless by changes in the habits of their possessors. They are not, however, shed or dropped bodily at once. No; they are *retained by heredity*, but *dwindle by disuse*, more and more, until they pass away entirely. But even when they are entirely gone in the adult, they are often found still lingering in the embryo. They are among the most obvious and convincing proofs of the origin of organic forms by derivation.

183

CHAPTER VIII.

PROOFS FROM GEOGRAPHICAL DISTRIBUTION OF ORGANISMS.

It is well known that the kinds of organisms found in widely-separated countries differ more or less conspicuously. The traveler in Australia or in Africa finds all, the traveler in Europe nearly all, the animals and plants wholly different from those he has been accustomed to see at home. Even the visitor from the Atlantic to the Pacific coast, if he observes at all, will find nearly all organisms strange to him. The facts of geographical diversity of organisms are so numerous and complex that, at first sight, they seem utterly lawless. Only recently this subject has been redeemed from chaos and reduced to something like order and law by the light thrown upon it by the theory of evolution. We will give, in very brief outline, the most important facts, and then show how they may be explained.

Geographical Faunas and Floras.—The group of animals and plants inhabiting any locality, whether peculiar to that locality or not, is called, in popular language, its fauna and flora. But, in a true scientific sense, a fauna and flora is a *natural* group of animals and plants in one place, *differing* more or less conspicuously from other groups in other places, and *separated from them by physico-geographical boundaries, or by physical conditions of some kind*. The members of such a group can only exist in certain harmonic relations with external conditions, and with one another. These relations with one another are often complex and nicely adjusted, so that change in one term is propagated through the whole series of terms, giving rise often to the most unexpected results, until finally a new equilibrium is established. Thus, the destruction of certain insectivorous birds, in mere wanton sport, may give rise to the multiplication of insect pests, and this to the destruction of certain kinds of plants, and this to the diminution of certain herbivores, and this in its turn to the disappearance of certain carnivores. It is well known that the introduction of rabbits into New Zealand and Australia has produced the most unexpectedly disastrous effect upon certain crops, on account of the absence of the fierce and active carnivores which keep in check their excessive multiplication in Europe.

184

Now, among the physical conditions which limit faunas and floras, and separate them from each other, the most important and universal is temperature.

Temperature-Regions.—If we travel from equator to pole, we pass through mean temperatures varying from 80° to 0°. This gives rise to a very regular zonal arrangement of plant-forms: 1. We have first a region in which palms and palm-like forms are abundant and characteristic, and which therefore may be called the region of palms. It corresponds with the tropic zone. 2. We next have a region in which hard-wood foliferous trees are most abundant and characteristic; first mostly evergreens and then deciduous trees, and therefore may be called the region of hard-wood forests. This corresponds with the temperate-zone. 3. Then we find a region characterized predominantly by pines and pine-like trees and birches, and may be called the region of pines. This is the sub-Arctic region. 4. Then a region without trees, but only shrubs and summer plants. This is the Arctic region. 5. And, finally, an almost wholly plantless region of perpetual ice—the polar region.

185

These regions are determined wholly by temperature, and therefore, in going up a mountain-slope to snowy summits, we pass through similar regions in smaller space. For example, in going from sea-level to the summits of the Sierra, 14,000 to 15,000 feet high, we commence in a region of predominantly hard-wood trees; but at 3,000 feet the forests become almost wholly coniferous, at 11,000 to 12,000 feet the vegetation becomes shrubby, and at 13,000 feet we reach perpetual snow.

We have taken plants first, because these, being fixed to the soil and incapable of voluntary seasonal migrations, are more strictly and simply limited by temperature—i. e., the arrangement of different kinds in zones is more simple and conspicuous. But the same rule holds also for animals. In

186

passing from equator to pole, animal kinds also change frequently, so that there are many temperature-faunas in which the animals are all very different. In both animals and plants, species, genera, families, etc., are limited by temperature. These are familiar facts; we recall them to the reader in order that we may base thereon a clearer definition of these limits.

More Perfect Definition of Regions.—1. The area over which any form spreads is called its *range*. Now, the range of a species is more restricted than that of a genus, because, when a species is limited by temperature, another species of the same genus may carry on the genus. For the same reason the range of a family is usually greater than that of a genus, and so on for higher classification-groups. For example, pines range on the slopes of the Sierra from about 2,000 feet to 11,000 feet, but not the same species. In ascending, we meet first the nut-pine (*Pinus Sabiniana*), then the yellow-pine (*P. ponderosa*), then the sugar-pine (*P. Lambertiana*), then the tamarack-pine (*P. contorta*), and last, the *Pinus flexilis*, etc.

FIG. 64.

2. Where two contiguous temperature-regions come in contact, there is no sharp line between; on the contrary, they *shade gradually*, almost imperceptibly, into one another, the ranges of species overlapping and interpenetrating, and the two species coexisting on the borders of their ranges. This is represented by the diagram (Fig. 64), in which the horizontal lines represent the north and south ranges of species of two groups, A and B, separated by the dotted line.

187

3. Species also pass out gradually on the borders of these ranges and others come in gradually, so far as number and vigor of individuals are concerned. If *a a'* and *b b'* (Fig. 65) represent the north and south range of two species, and *b a'* their overlap or area of coexistence, then the height of the curves A and B will represent the number and vigor of the individuals in different parts of the range.

FIG. 65.

4. While, therefore, there is a shading of contiguous groups into each other by overlap of species-ranges; while there is also a gradual passing out of species so far as number and vigor of individuals is concerned, yet, in *specific characters* we observe usually no such gradation. Species seem to come in on one border with all their specific characters perfect, remain substantially unchanged throughout their range, and pass out on the other border, still the same species. In other words, one species takes the place of another, usually by *substitution*, not by *transmutation*. It is *as if* species had originated, no matter how, each in its own region, and had spread in all directions as far as physical conditions and struggle with other species would allow. This important subject will be more fully discussed later.

188

5. We have thus far spoken of species as limited by temperature alone, but they are limited also by *barriers*. If, then, there be an east and west barrier, such as a high mountain-range, or a wide sea or desert, there will be no shading or gradation of any kind, because the barrier prevents overlapping, interpenetration, and struggle on the margins. For example: The species north and south of the

Himalayas, or north and south of Sahara, are widely different. It is, again, *as if* they originated each where we find them and spread as far as they could, but the physical barrier prevented mingling and shading.

6. There are temperature-regions south as well as north of the equator. Now, although the climatic conditions are quite similar, the species of corresponding temperature-regions north and south are wholly different. It is, again, as if they originated where we find them, and were kept separate by the barrier of tropical heat between. If carried over, they often do perfectly well.

Continental Faunas and Floras.

If the land-surfaces were continuous all around the globe, there is little doubt that each temperature region with its characteristic species would also be substantially continuous. There would, it is true, be some local variations dependent upon soil and humidity, etc., but substantially the same species would exist all around. The distribution would be almost wholly zonal. But the intervening oceans are complete barriers to continental species. Hence we ought to expect, and do find, that the faunas and floras of different continents are almost totally different. Each apparently originated on its own continent, and did not spread to other continents, only because they could not get there. It is necessary to explain this in more detail.

189

FIG. 66.—Polar projection of the earth. 1, tropical; 2, temperate; 3, sub-arctic; 4, arctic; 5, polar regions.

[Fig. 66](#) represents a polar view of the earth, showing the eastern and western continents, and the five temperature zones already described. Now, if we examine the species in each region, commencing at the pole, we find that those of Nos. 5 and 4 are almost identical all around. The reason is obvious. The continents come close together there, with ice-connection if not land-connection all around. There is but one circumpolar region. But, as soon as we come down to No. 3 and No. 2, the species on the two continents are nearly all different, because there is an impassable barrier between, either in the form of ocean or of Arctic cold. For example, the animals and plants inhabiting the United States are almost wholly different from those in Europe, not only in species, but even largely in genera and to some extent in families. There are some exceptions to this rule, but these are of the kind which prove the rule, or rather the principle on which the rule is founded. These exceptions are mainly of three kinds: 1. *Introduced species*.—All our weeds, many garden-plants, and many animal pests are of this

190

kind. They were not found here when America was discovered, only because they could not get here; for, when brought here, they do so well that they often overrun the country and dispossess the native species, as we ourselves have done the Indians. 2. *Hardy or else wide-migrating species*.—Hardy species have wide range; they may belong to No. 4 as well as No. 3. If so, they range down to No. 3 on both continents. Migrating birds, such as ducks and geese, etc., breed in summer in No. 4, and migrate southward in winter on both continents from the common circumpolar ground. 3. *Alpine species*.—It is a curious fact that species on tops of snowy mountains in temperate regions of the two continents are wonderfully similar, though so completely isolated. We are not yet prepared to discuss this point. We shall do so later. Suffice it to say now that it can be completely explained.

In region No. 1 the continental diversity is still greater. Not only species and genera, but whole families and even orders, are peculiar to each continent. The great pachyderms—elephant, rhinoceros, hippopotamus—are peculiar to the Eastern; the edentates—sloths and armadillos—to the Western. The humming-birds, those gems of the forests, of which there are over four hundred species, and the whole cactus family, are peculiar to America, while the tailless monkeys are equally characteristic of the Eastern Continent.

191

The continents do not come together again toward the south, and, therefore, as might be expected, the great difference between the two persists to the southern points. The faunas of the southern points of South America, Africa, and Australia are very different.

Subdivisions of Continental Faunas and Floras.—Besides the subdivisions of continental faunas, north and south, determined by temperature as already explained, if there be in any continent an impassable barrier running north and south, there will be a corresponding difference in the species on the two sides, east and west. We give but one example: The North American Cordilleras or Rocky Mountains, with their high ranges and desert plains, constitute a very great barrier between the eastern and western portions of the United States. Hence, we find an extraordinary difference between the species inhabiting California and those found in the eastern portion of the country. Speaking generally, all the species and many of the genera are peculiar. The exceptions, too, are significant. Leaving out introduced species, of which there are many, they are mostly strong-winged or widely-migrating birds, such as the turtle-dove, the turkey-buzzard, the bald eagle, and, of course, many water-birds.

192

Special Cases.—If any body of land is widely separated from all other lands by deep seas, we invariably find a corresponding peculiarity of its species. Thus, the species inhabiting Australia and Madagascar are perhaps the most peculiar in the world. We do not dwell further on these, because we will discuss them hereafter. There is a little group of very small islands—the Galapagos—about six hundred miles off the western coast of South America, and surrounded on all sides by deep sea. These islands are stocked with a collection of curious animals not found elsewhere on the surface of the earth; but among them are no mammals at all. We might multiply examples without limit. Even the rivers emptying in the same sea sometimes have each its peculiar species of mussels. In the Altamaha River there are several species of unios—such, for instance, as the wonderful spinous unio—not found elsewhere. How came they there? Howsoever they may have come there, they are now kept isolated there by barriers of land and of salt water.

Many other curious details will come up in our discussion of the origin of diversity.

Marine Species.—Precisely the same principles apply here; but diversity in the case of marine species is perhaps less marked, and certainly less general, because of the universal oceanic connection. Open-sea species are therefore almost universal. But many marine species are confined to shallow water, and therefore to shore-lines. The species on the two shores of the same ocean, or the two coasts of the same continent, are different, being isolated east and west by barriers of deep sea or of land, and north and south by temperature. Also about isolated lands, like Australia and Madagascar, the species are peculiar.

193

Thus, then, species, genera, etc., are limited in every direction; north and south by temperature, and in all directions by barriers, in the form of oceans, deserts, and mountain-chains. Add to these, peculiar climates and soils, and we see that, from this point of view, the whole surface of the earth may be divided and sub-divided into regions, sub-regions, provinces, etc. It would carry us too far to

explain the primary and secondary divisions adopted by Mr. Wallace, and the somewhat different ones suggested by Mr. Allen. Our main object is to discuss the *cause* of this diversity, and especially to show the light shed upon it by the theory of evolution. We have only given a sketch of the facts sufficient for this purpose.

Theory of the Origin of Geographical Diversity.

It will be observed that all along we have assumed a sort of provisional theory. We have said in every case, it is *as if* organic forms originated where we find them, and have gone thence wherever they could—as far in every direction as physical conditions and struggle with competing species would allow. This view has been formulated as the “theory of specific centers of origin.” There would be less objection to this as a first provisional theory did it not assume a supernatural *mode* of origin. But, in the minds of those who hold it, it has usually assumed expressly or tacitly the form of “*specific centers of creation*,” thus implying the immutability of specific types and the supernaturalism of specific origin ([page 68](#)). In this latter or usual form it completely fails to account for the facts given above. For, if this were the mode of origin, each species ought in every case to be perfectly adapted to its own environment, and to no other. But, on the contrary, introduced species often flourish better than in their own country, and better than the natives of their new homes. In the less objectionable form of “specific centers of origin,” without defining the mode of origin, it accounts well for many of the more obvious facts of geographical diversity, as it *now* exists, but not all. According to this view, the amount of diversity ought to be in strict proportion to the completeness of isolation, or impassableness of the separating barriers; but this is not *exactly* true. There is another element, not yet mentioned, which is just as important as impassableness, but which until recently has been left entirely out of account. This is the element of *time*—the amount of time since the barrier was set up, or during which it has continued to exist. These two elements, it is true, are closely connected with each other; for, since all changes in physical geography have taken place very slowly—since barriers in the form of mountain-ranges and seas have increased by slow process of growth—it is evident that impassableness is, to some extent, a measure of time. But they are by no means in strict proportion. The one or the other may predominate.

194

195

Now, this time-element connects geographical distribution with changes of physical geography and climate in *geological* times, and especially with the *latest* of these changes, viz., those occurring during the *Glacial epoch*. During that remarkable epoch extraordinary changes of climate, from extreme Arctic rigor to great mildness, enforced wide migrations of species southward and northward; while concomitant changes of physical geography, by elevation of the earth’s crust over wide areas, opened highways between previously-isolated continents, permitting migrations in various directions, and by subsequent depression again isolating the migrated species in their new homes. It is evident, then, that the recognition of the element of almost unlimited time at once introduces into the question of geographical distribution the *idea of evolution*. If the study of geographical distribution, as it *now exists*, and as a part of science of physical geography, gave rise naturally to the theory of “specific centers of origin,” the study of the same, in connection with geological time, and as a part of geological science, now demands its explanation by the theory of evolution.

196

It must be borne in mind, then, that geographical diversity of organisms is not a question of the present epoch only. There has been geographical diversity in every previous geological epoch; it is, therefore, a question of geology as well as of biology. It is probable, however, that diversity has increased with the course of geological times, and is greater now than ever before. In other words, in the evolution of the organic kingdom, the law of differentiation has prevailed here, as in other departments of biology. A clear statement of the causes of the *present* distribution of organisms must embrace also the causes of geographical diversity *generally*. We give, therefore, at once a brief statement of what seems to us the most probable view, and shall then proceed to show how it explains the present distribution.

Most Probable View of the General Process.—Bearing in mind, then, this time-element, the phenomena of geographical diversity are best explained by the following suppositions: 1. A gradual progressive movement (evolution) of the organic kingdom, marching, as it were, abreast, at equal rate along the whole line—i. e., in all parts of the earth, and throughout all geological times, under the action of all the forces or factors, and following all the laws, of evolution already explained (pages 19 and 73). If this were all, there would be no *geographical* diversity, although *organic diversity* might be as great as it is now. There would be differentiation of forms and structure everywhere, but no differentiation of groups in different localities. 2. Under the influence of different conditions in different places, more or less isolated from one another by climatic or physical barriers, the onward movement (evolution) of organic forms takes different directions and different rates, and gives rise to local groups, which become more and more differentiated, without limit as time goes on. This element, acting by itself throughout all geological times, would ere this have produced an extreme geographical diversity, such as does not anywhere exist. 3. From time to time, at long intervals, extensive changes of physical geography and climate, produced by crust elevations, partly enforced by change of temperature, and partly permitted by opening of gateways, extensive migrations and dispersals of species, by which mingling and struggle for life and final readjustment takes place, and extreme diversity is prevented. Such mingling of different faunas and floras on the same ground, and the severe struggle for life that thus ensues, and the survival of the fittest in many directions, are, as already shown, among the most powerful factors of evolution. They tend to *increase organic* diversity, but to *diminish geographical* diversity. 4. At the close of such great periods of change as indicated in the last, by contrary movement of the earth-crust—i. e., subsidence—new barriers are set up and new isolations are produced, and the process of divergence again commences and increases steadily so long as the barriers continue to exist.

197

198

Now, the last of these periods of great changes and extensive migrations, and subsequent isolations, was the Glacial epoch. It was this epoch, therefore, which mainly determined the present geographical distribution of species. Thus, the present distribution is a key to the directions of the last great migrations, and therefore to the nature of the changes in physical geography and climate which then occurred; and, conversely, the character of these changes, determined in other ways, *furnishes the only key to the present distribution of species.*

Before applying the foregoing principles in the explanation of special cases, it may be well to give a very brief outline of the condition of things during the Glacial epoch.

In America, during this epoch, by increasing cold the southern margin of the great northern ice-sheet crept slowly southward, until it reached the latitude of about 38° to 40°. Arctic species were thus driven southward slowly, from generation to generation, until they occupied the whole of the United States, as far as the shores of the Gulf, while temperate species were forced still farther south, into Central and South America. This period of extreme rigor and southward migration was followed by a period of great mildness, during which the ice and its accompanying Arctic conditions retreated northward, followed by Arctic species. More than one advance and retreat, apparently, occurred during this time. Again, during the same time, brought about by northern elevation, there was broader connection than now exists between North and South America, and free migrations between, in both directions, enforced by extreme changes in temperature. Also, during this or previous time, there were broad connections between North America and Asia, in the region of Behring Strait, and between America and Europe, in high-latitude regions, and extensive migrations of faunas and floras between were thus permitted. The necessary result of all these migrations of species, partly enforced by changes of climate, partly permitted by opening of gateways since closed, was exceptionally rapid changes in organic forms. This was the result of two causes: First, the severer pressure of a changing physical environment; and, second, a severer struggle for life between the natives and the invaders.

199

In Europe, during the same time and from similar causes, there were at least three or four different faunas struggling together for mastery on the same soil. First, there were the Pliocene indigenes, who had, if any, pre-emption right to the soil; second, invaders from Arctic regions, driven southward by increasing cold; third, invaders from Asia, permitted by the removal of the old sea-barrier which once extended from the Black Sea to the Arctic, and of which the Caspian and Aral are existing remnants,

and thus opening a gateway for migration which has remained open ever since; fourth, invaders from Europe and Asia into Africa, and sometimes back again into Europe, by opening of gateways through the Mediterranean, which have been since closed. One of these highways was through Gibraltar, and one from Italy to Africa through Sicily. As in America, so here, in even greater degree, the severe pressure of changing environment and the severe struggle for life produced rapid changes of organic forms. Many species were destroyed; others saved themselves by modifications adapted more perfectly to the changed conditions. There is little doubt that man came into Europe with the Asiatic invasion, and was one of the principal agents of change, especially in the way of destruction of many old forms.

Such is a very brief outline of the last great geological change and its general results. Being the last, this one has left the strongest and most universal impress on the *present* geographical distribution. But similar changes by crust oscillations, if not also by extreme changes of climate, have repeatedly occurred in geological times, and some of the most remarkable geographical faunas and floras are the result of these earlier geological changes. We will now give a few examples illustrating these principles:

1. *Australia* is undoubtedly more peculiar in its fauna and flora than any other known country. Not only are all its species peculiar, not found elsewhere on the face of the earth, but its genera, its families, and even many of its orders of animals and plants, are also peculiar. These facts are so familiar that it is unnecessary to dwell on them. I need only mention, among plants, the whole of the simple-leaved acacias, already mentioned on [page 86](#), of which there are so many species, and the whole family of the eucalyptids, of which there are several hundred species. Among animals I need mention only the order of monotremes, or egg-laying mammals, and nearly the whole order of marsupials, or pouched animals, of which there are over two hundred species. On the other hand, the true typical mammals are entirely absent, with the exception of a few bats and a few rats, which have evidently been accidentally introduced from abroad.

Another very noteworthy fact, which must be taken in connection with the last, is that Australian forms are far less advanced in the race of evolution than those of any other country—i. e., that many old forms which have long ago become extinct elsewhere are still retained there. A few examples will suffice. The marsupials just mentioned are an old form once universally distributed, but now nearly extinct everywhere, except in Australia; the cestracion, or Port Jackson shark, and the ceratodus, are Palæozoic and Mesozoic forms retained only in Australia.

What is the explanation of these remarkable facts? We find the sufficient answer in the fact that Australia has been long isolated from all other countries. While geographical changes in geological times have mingled more or less the organic forms of other countries, and the sharp struggle for life has produced more rapid advance and the production of many new and higher forms better armed for the battle of life, Australia has remained isolated from competition, and therefore comparatively unprogressive.

Can we tell when Australia was finally isolated? Approximately we can. The class of mammals is divided into two groups, which differ widely from each other; so widely, that they are called sub-classes. These are placental mammals, or true typical mammals, and non-placental or reptilian mammals. The non-placentals include only the marsupials and the monotremes (ornithorhyncus and echidna). The monotremes actually lay eggs and incubate them. In the marsupials the embryo has no placental connection with the mother, and is born in a very imperfect condition, utterly unfit for independent life, and placed in the pouch (marsupium), and *permanently* attached there to the teat until it is capable of independent life; after which only it voluntarily nurses like other new-borns. In other words, the gestation commenced in the womb is completed in the pouch. The uterine gestation in the opossum is only seventeen days, while the marsupial gestation is about two and a half months. In a kangaroo seven feet high in sitting position the embryo at birth is only one inch long—a pink, hairless, almost amorphous mass. The monotremes are pure oviparous animals, like birds and reptiles. The marsupials might well be called *semi-oviparous*. In pure egg-layers the whole embryonic development is outside of the body; in pure young-bearers the whole is within the body; in marsupials it is partly within and partly without. Now—1. The monotremes are found nowhere but in Australia and the

neighboring New Guinea. 2. The marsupials are also all confined to the Australian region, except a few opossums in America. 3. There are some two hundred and thirty species of non-placentals in the Australian region. 4. As already said, there are no true mammals at all in Australia, except a few bats and rats which have come accidentally from abroad. 5. But non-placentals existed abundantly in *Mesozoic times everywhere*, both in Europ-Asia and in America, while true mammals did not appear at all on the surface of the earth until the *Tertiary*, when they almost immediately became very abundant everywhere, except in Australia. *Evidently, therefore, Australia was isolated before the Tertiary*. The enormous difference between its fauna and flora and those of other countries is due to at least three things: 1. So long an isolation necessarily produced great divergence of forms. This alone, however, would not affect the *grade of organization*. 2. Saved from wide migrations, and especially invasions from Eurasia, the great field of competitive struggle, it was left far behind in the race of evolution. Hence many of its forms are archaic; its mammalian fauna, for instance, is still in the Mesozoic stage. 3. Its distance from other large continents is so great that accidental colonization has been very slight, only extending to a few bats and a few rats.

I stop a moment to insist on the effect of competitive struggle in developing organic forms strong for the battle of life. Of all the continents, Eurasia has been the scene of most frequent geological changes, and therefore the arena of fiercest competitive struggle through wide and frequent migrations. Eurasian species, therefore, are the strongest of all. They have conquered wherever they have gone. Species in isolated regions are usually the weakest. The great moas and the dodo could not have continued to exist unless protected in a sort of bomb-proof. Kangaroos would now be quickly exterminated by the introduction of fierce Eurasian carnivores.

204

2. *Africa*.—The fauna of that part of Africa north of Sahara is essentially Mediterranean—i. e., a sub-group of the Eurasian. Sahara, rather than the Mediterranean Sea, is the true intercontinental barrier. The true African region, therefore, is south of Sahara. Now, according to Mr. Wallace, whom I mainly follow here, the true African mammalian fauna consists of two very different groups of animals. The one is a group of very small, curious animals, mostly low forms of insectivores and lemurs, very peculiar to this region, though more resembling those of Madagascar than of any other region; the other is a group of large and powerful animals which dominate the region. These latter are similar to, though not identical with, those which inhabited Eurasia in Pliocene times. The great carnivores, pachyderms, and ruminants of the region are examples of this group. Now, the explanation of these facts is as follows: The indigenes of Africa are the animals of the first group. Africa, in Tertiary times, was isolated from the great field of combat, Eurasia, and therefore its animals were small, of low grade, and peculiar. During later Tertiary (Pliocene) times, then, Africa was inhabited by animals of the first group, while Eurasia was dominated by animals of the second group. These two groups were then separated by the Desert of Sahara, or else by a sea in that region. Some time during the Glacial epoch geographical changes removed this barrier, and climatic changes drove the Eurasian animals southward into Africa, where, finding congenial climate, they took possession of the continent, dominating the feebler natives. Subsequently they were isolated there by the formation of the desert, and the process of divergence commenced, and has gone on to the formation of many new forms. Meanwhile the change, partly by extinction and partly by modification, has gone on still more rapidly in Eurasia, but in a different direction. Hence, Africa is regarded as one of the primary faunal regions.

205

3. *Madagascar*.—This, next to the Australian, is probably the most peculiar faunal region known. There is probably not a single mammalian species found there which is known to occur anywhere else. It is remarkable also as the principal home of that strange, generalized, ancient form of monkeys—the lemurs. And yet its animals, though very different, have a distant resemblance to those of Africa; not, however, to the present dominant type, but to those we have called the indigenes. Not one of the northern invaders is found there. The obvious conclusion from these facts is, that Madagascar was formerly united with Africa, and both were occupied by the same mammalian fauna (which may be called African indigenes, although they were considerably different from their descendants of the present day), but became separated before the northern invasion. The effect of this invasion was to hasten the steps of change in the indigenous fauna of Africa, partly by extermination, partly by modification, while the isolated portion in Madagascar went on at the usual slow rate of change in

206

isolated regions. The time since the separation (which was certainly during the Tertiary period) has been sufficiently long to produce very great divergence in both, but *especially in the African indigenes*. In the fauna of Madagascar, therefore, we have a nearer approach to the original fauna of both. On account of this long isolation, we have here many ancient types which are extinct elsewhere. The lemurs are such an ancient type. These are a wonderfully-generalized type of monkeys—a connecting link between monkeys and other mammals, especially insectivores. As might be supposed, from the law of differentiation, already explained ([page 11](#)), they are the earliest form, the progenitors, of monkeys. In fact, in early Tertiary times, they were found not only in Africa and Madagascar, but all over the earth, as the only representatives of the monkey family. The true monkeys were not introduced until the mid-Tertiary. In Eurasia and in America (which at that time was probably connected with Eurasia) wide migrations and frequent conflicts of faunas produced comparatively rapid evolution of new and higher forms, while in isolated Africa old types continued until the invasion. Madagascar was spared this invasion, and therefore old types are still preserved there. At present, at least three quarters of all lemurs are confined to Madagascar, although a few species are still found in Africa and in the great East Indian islands.

207

4. Island-Life.—Mr. Wallace has divided islands into two kinds, continental and oceanic islands. The division is undoubtedly a good one, although we may not always be able to refer an example with certainty to the one or the other class. *Continental* islands are those on the borders of continents, and separated from the latter only by *shallow water*. *Oceanic* islands are those, usually very small, found in the midst of the ocean, with abyssal depth all about. Continental islands may be regarded as appendages to the neighboring continent—as outliers of continents separated by submergence, and have, in fact, been thus formed. Oceanic islands have been formed geologically recently by volcanic action building up from the sea-bottom. Continental islands have a continental structure—i. e., they are composed of stratified as well as of igneous rocks. Their structure is a record of geological history, like that of the neighboring continent. Oceanic islands are composed wholly of volcanic rocks; or, if there be any stratified rocks, these are only of the most recent date. As examples of continental islands we have New Zealand as an appendage of Australia, the great East Indian (Borneo, Java, Sumatra, etc.) and the Japanese Islands, etc., as appendages of Asia; the British Islands, appendages of Europe; the West Indian Islands, appendages of America; Madagascar, an appendage of Africa, etc., etc. As examples of oceanic islands we have the Azores and Bermudas in the Atlantic, and the Polynesian islands in mid-Pacific.

208

a. Continental Islands.—Now, the fauna of continental islands, as might be expected from the mode of origin of these islands, is similar to, though not identical with, that of the neighboring continent; the amount of difference being in proportion to the *length of time since* they were separated and the *width of the separation*. *Madagascar*, for example, has been long separated from its parent continent, and by a wide and deep channel. Its fauna, therefore, differs greatly from that of Africa, although resembling it more than that of any other country. The separation of *New Zealand* from Australia has been not quite so long, and the divergence, therefore, is not so great. These two will be sufficient illustrative examples of long separation, and therefore of great differentiation of forms.

**FIG. 67.—Map of outline of coast of Western Europe, if elevated
600 feet (after Lyell).**

On the other hand, the British Isles are an excellent example of comparatively recent separation. These isles have probably been several times united and separated from Europe, but we are here concerned only with the more recent. They are now separated from the continent and from one another only by shallow seas. An elevation of less than six hundred feet—geologically a very small change—would bare the bottoms of the Irish and English Channels and the North Sea, and connect these islands with one another and with the continent ([Fig. 67](#)). Now, it is well known that there were during the Glacial epoch, and subsequently, several oscillations of level sufficient to connect and separate these islands. In the mid-Glacial epoch the British Islands, by submergence, were nearly obliterated, being reduced to an archipelago of small islets representing the high mountains of Wales and Scotland. The Pliocene fauna and flora were, therefore, largely exterminated. During the close of that epoch they were elevated above the present condition and broadly connected with the continent ([Fig. 67](#)), and the newly-exposed land was taken possession of by European species, man among the number. Still later—i. e., at the beginning of the present epoch—the islands by subsidence were again separated, but not widely, from the continent. This is the condition now. What, then, was the result? 1. The fauna and flora of the British Isles are substantially the same, but *less rich* in species than that of Continental Europe, some of the European species being wanting. This shows that the last connection was not a long one; the colonization had not been completed before re-isolation. 2. This poverty of species is

209

more conspicuous in Ireland, because colonization is progressive in space as well as in time. Some species had not reached so far when Ireland was re-isolated from England. The conspicuous absence of snakes, for example, is thus accounted for. There is, we all know, another theory to account for this, but we prefer the natural one. 3. The difference between British and European fauna and flora is very small, it is true, but there is some difference, varietal if not specific. The reason is, that the time since separation is too small to produce much divergence, and the width of the existing barriers not great enough to prevent colonization by accidental causes.

211

The continental islands of the southern coast of Asia are good examples of an intermediate condition as to the length of time since separation, and of the consequent degree of differentiation of the faunas and floras.

Coast-Islands of California.—We give one more example, and dwell upon it a little, because it occurs on our own coast.

The recent studies of Mr. E. L. Greene on the flora of the islands off the coast of California have brought to light some facts which are an admirable illustration of the principles laid down above.

On looking at a good map of California, any one will observe eight or ten islands, some of them of considerable size, strung along the coast from Point Conception southward, and separated from the mainland by a sound twenty to thirty miles wide. They are in structure true continental islands—outliers of the mainland separated by a subsidence of a few hundred feet. Moreover, the date of their separation is known. They were certainly connected with the mainland during the later Pliocene and early Quaternary, for bones of the mammoth, characteristic of that time, have been found on one of them.²⁸ They were therefore separated during the Glacial epoch.

212

The main peculiarities of the flora of these islands are the following:

1. Out of nearly three hundred species of plants gathered by Mr. Greene, about fifty are wholly peculiar to these islands. 2. Of the remaining two hundred and fifty species, nearly all are distinctively Californian. In other words, the distinctively Californian forms are very abundant, while the common American forms are rare—i. e., the island flora is distinctively Californian, with many peculiar species added.

I explain these facts as follows: The whole coast-region of California is geologically very recent, having emerged from the sea as late as the beginning of the Pliocene epoch. As soon as emerged it was of course colonized from adjacent parts. Since that time its peculiar flora has been formed by gradual modification. The environment has been sufficiently peculiar, the isolation sufficiently complete, and the time sufficiently long, to make a very distinct group of organisms. It is one of Mr. Wallace's primary divisions of the Ne-arctic region.

During late Pliocene and early Quaternary times, as already said, the islands were still a part of the mainland, and the whole was occupied by the same species, viz., the distinctively Californian species now found in both, together, as I suppose, with the peculiar island species. During the oscillations of the glacial times the islands were separated by subsidence of the continental margin. Simultaneously with this subsidence, or subsequently thereto, came the invasion of northern species, driven southward by glacial cold. Then came the mingling of invaders with natives, the struggle for mastery, the extermination of many forms—viz., the peculiar island species—and the slight modification of others, and the final result is the California flora of to-day. But the island flora was spared this invasion by isolation. Therefore the invading species are mostly wanting, the distinctive island species were saved, and the result is the island flora of to-day. The island flora, therefore, somewhat nearly represents the Pliocene indigenes of both.

213

It will be observed that this case is somewhat like that of Madagascar, but with a characteristic difference. In the case of Madagascar, the separation has been long. The extreme peculiarity of its fauna is the result partly of progressive divergence and partly of many forms saved by isolation. In the case of the coast-islands of California, the time has not been long enough for any great divergence by modification. The peculiarity of its species is due almost wholly to species saved by isolation.²⁹

b. Oceanic Islands.—We have seen that faunas and floras of continental islands are somewhat similar to those of the neighboring continent, though with varying degrees of difference—the amount of difference, or divergence by evolution, being in proportion to the amount of time and the impassableness of the separating barriers. But oceanic islands have never been connected with any continent. They are new land formed in the midst of the ocean by volcanic action. When they first appeared they were, of course, without inhabitants of any kind, animal or vegetal. How were they peopled? We answer by *waiifs* from here and there—by *castaways from other lands*. The dominance of particular kinds will depend on the direction of winds and currents, bringing from some lands more than others, and upon the kinds of animals or seeds of plants most liable to be successfully carried across wide seas. Their faunas and floras, therefore, are characterized by a mixture of species resembling, though not usually identical with, those of various lands, with a predominance of those of some one land, and by the singular and complete absence of mammals and amphibians, these being unlikely to be transported by floating timber, as are small reptiles and insects, etc. Among mammals, however, there is a significant exception in favor of bats, the reason being both their power of flight and their habit of concealment in hollow trees, etc. To this explanation, however, we must add that divergence by isolation will meanwhile go on in proportion to time. The Azores, for example, have been peopled from Europe, Africa, and America, but mostly from Europe, on account of the prevailing winds and currents being favorable to colonization from that direction. There are many curious peculiarities in the species, however, because colonization is very slow, and divergent variation has been going on *pari passu*. The Bermudas, on the other hand, have been colonized mainly from America, because of the current of the Gulf Stream.

214

215

These few examples are sufficient for our purpose, which is only to illustrate the causes of geographical distribution. If any one desires to pursue this interesting subject, we would refer him to that most fascinating book, Mr. Wallace's "Island-Life."

5. Alpine Species.—These afford an admirable illustration of the fact that in isolated faunas and floras the amount of difference is proportioned not only to the completeness of isolation, but also and mainly to the *time of isolation*.

It is well known that Alpine species—i. e., those species inhabiting the region bordering the perpetual snow of lofty mountains—are very similar to one another, even in the most distant localities, where their isolation from one another is as complete as possible; as, for example, in the high Alps of Europe, the high mountains of Colorado and California. Why is this? We find the key to this mystery in the additional fact that *they are similar also to Arctic species*. A somewhat full explanation is here necessary.

During Miocene times, magnolias and taxodiums (bald cypress), like those in forests and swamps of Carolina and Louisiana, and sequoias and libocedrus like those now in California, and many other temperate-region forms of plants, grew abundantly in Greenland, and northward certainly to 75° north latitude. At that time there could not have been any perpetual polar ice, and therefore no Arctic species, unless on *high mountains in polar regions*. In Pliocene times perpetual polar ice, and therefore Arctic species, probably commenced to appear. As the cold of the Glacial epoch came on and increased in severity, the polar ice extended southward as a general ice-sheet, until it reached in America 40° and in Europe about 50° north latitude. In the United States its margin can be traced as a distinct moraine through Long Island, middle New Jersey, middle Pennsylvania; thence, less distinctly, following the Ohio River, crossing the Mississippi; thence following the Missouri, on its south side, into Montana. By the increasing cold, Arctic species were driven slowly southward, generation after generation, until they occupied the whole of the United States to the Gulf, and the whole of Europe to the Mediterranean. As these species on the two continents came from a *common home* in polar regions, they were similar to one another, except in so far as some slight divergent modification may have been produced during their southward travel. When the glacial rigor declined, and the ice-sheet gradually retreated to its present position, Arctic species, following the snow-edge, went also northward, on both continents, to their present home in polar regions. But there was an alternative way of migration left open which was embraced by certain plants and insects. While on both continents most individuals went northward, some of them went upward, following the snow-edge into high mountains, and were

216

217

left *stranded there*. Thus it has come to pass that the plants and insects of high mountains in temperate regions of different continents, though so widely separated and impassably isolated, are extremely similar to one another. But, though similar, they are rarely identical. The time has been long enough for some but not very great divergent modification. It is impossible to conceive a more beautiful illustration of the principles we have been trying to enforce.

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Thus, then, undoubtedly all the phenomena of geographical distribution of species are most rationally explained on the principle of slow evolution—changes, different in different places, and increasing with the time of isolation and its completeness.

Objection.—The only objection which can be raised against this view is the manner in which contiguous geographical faunas and floras pass into one another when they are *limited not by barriers but by temperature*. In passing from equator to poles, over continuous land, we of course pass through many successive faunas and floras, limited wholly or mainly by temperature. Now, if species are indeed indefinitely modifiable, then on the borders of contiguous faunas or floras, where one species disappears and another closely allied but adapted to a colder temperature takes its place, the one species (say the anti-evolutionists) ought to be gradually *transmuted* into the other, so that all the gradations may be traced. But this is certainly not usually the fact. On the contrary, a species may indeed pass out gradually, and another come in gradually, so far as *number and vigor of individuals are concerned*; but, in *specific character*, they may be said, usually at least, to come in suddenly, with all their characters perfect, remain unchanged throughout their whole range, and pass out suddenly at its borders. Another species takes its place, overlapping in range and coexisting on the borders of both; this also continues unchanged, as far as it goes, and so on. The change from one fauna to another is apparently not by *transmutation* of one species *into* another by gradations, but by *substitution* of one perfect species *for* another perfect species. As a broad general statement, the condition of things is precisely such as would be the case if specific types were substantially immutable by physical conditions, but were originated in some inscrutable way (created) in the regions where we now find them, and have spread in every direction as far as physical conditions and struggle with other species would allow them—their ranges therefore interpenetrating and overlapping one another on their borders.

218

Two characteristic examples will make our meaning clear. There is not a more characteristic tree known than the sweet-gum, or liquidambar. This tree grows from the borders of Florida to the shores of the Great Lakes. It may indeed be most numerous and vigorous somewhere in the middle region, and may die out gradually in number and vigor of individuals on the borders of its range, but in specific character it is substantially the same throughout, easily recognizable by its dense wood, its winged bark, its five-starred leaf, its spinous burr, and its fragrant gum. Physical conditions may diminish its number and vigor, and limit its extension, but seem powerless to essentially modify its specific character. It seems to give up its life rather than change its nature.

219

Another striking example: The sequoias (redwood and big-tree) are entirely confined to California, and there are only two species now existing, viz., the redwood (*S. sempervirens*) of the Coast Ranges, and the big-tree (*S. gigantea*) of the Sierra Nevada. Doubtless they are most numerous and vigorous somewhere in the middle of their range, and die out gradually in number and vigor on the borders north and south, being replaced there by other genera better adapted to the physical conditions; but in specific character they remain essentially unchanged throughout. They are everywhere the same—easily recognizable by wood, bark, leaf, and burr. Both in this case, and in the previous one of the sweet-gum, it is as if they were created perfect in their present localities, and have spread in all directions as far as physical conditions and the struggle with other competing species would allow; but physical conditions seem powerless to change them into any other species by adaptive modification.

Answer.—We have, we believe, stated the objection fairly. The answer is, that the elements of *time* and of *migrations* have not been taken into the account. In fact, this objection was conceived and formulated before the idea of geological time was fully assimilated by the human mind, and our theories of origin adjusted to it. If these species did indeed originate where we now find them, and *in*

220

the present geological epoch, the argument might at least be entertained; but this is not the fact. We know something of the geological history of all these species, and the history of the migrations of some of them. We know that sweet-gums were abundant and of *many species* in the United States in Tertiary times, and all have become extinct except this remnant. Whatever of modifications there were must be looked for at or about the time of its origin in Tertiary times, not now. Species, like individuals, are plastic only when young. This one has already become rigid, and all the more so as it is a remnant widely separated from other species. For competition is strongest and most effective with nearest allies. Present species are mostly isolated remnants—terminal twiglets of the tree of life. Twiglets are of course widely separated at their visible ends. Their points of union with other twiglets must be sought below.

In the case of the sequoias, we know something also of the history of their migrations. In Miocene times they were abundant, and of many species in circumpolar regions. Some twenty-four species of fossil sequoias are known, fourteen of which are Tertiary. By the cold of the Glacial epoch they were driven slowly southward, both in America and in Europe—in America as far as Southern California. After the Glacial epoch, and the return of temperate conditions, they doubtless attempted to go northward again; but these great changes were too much for them; they were wholly exterminated in Europe, and nearly so in America. A few were left stranded high up on the slopes of the Sierra Nevada, and on the cool, moist slopes of the Coast Ranges. The species now in California are not identical with those found in the Miocene strata of Greenland; but the difference is only what we might expect after such extensive migrations and such long and severe struggle for life. Further, it is noteworthy that the Miocene species fall into two groups, viz., the yew-like leaved and the cypress-like leaved. These are represented to-day in California, the one by the redwood, the other by the big-tree. They are evidently direct descendants of the Miocene species, though somewhat modified.

221

But it will be objected that there ought to be some cases of transitional forms showing transmutation—in fact, there ought to be some cases of species now forming under our eyes. There are, we believe, examples of such cases. But intermediate forms are not likely to be maintained long, especially if migrations occur to give rise to severe conflict of forms. In that case the intermediate forms are soon eliminated, and species become distinct. This important point will be discussed more fully in the next chapter.

222

CHAPTER IX.

PROOFS FROM VARIATION OF ORGANIC FORMS, ARTIFICIAL AND NATURAL.

As already stated, [page 40](#), the use of the method of experiment in the field of biology is, unfortunately, very limited. Nevertheless, it is already beginning to be used more and more in the department of physiology, and may be used also, to a limited extent, in the department of morphology. It is true that direct *scientific* experiments, for the express purpose of producing permanent modifications of form, and thus testing the theory of evolution, are of comparatively little value as yet, because the all-important element of time is wanting. The steps of evolution are so slow, and the time necessary to produce any sensible effect is usually so great, that, in comparison, man's individual lifetime is almost a vanishing quantity. But, from time immemorial, experiments have been *unconsciously* made by man on domestic animals and food-plants, which bear directly on this subject. All domestic animals and food-plants, and many ornamental flowering plants, have been subjected for ages to a process of artificial selection acting upon natural variation of offspring. As wild species are modified, we believe, indefinitely by divergent variation and *natural* selection, so domestic species are modifiable certainly largely, perhaps indefinitely, by divergent variation and *artificial* selection by man. We all know the extraordinary modifications which have thus been gradually brought about in domestic animals, such as dogs, horses, sheep, pigeons, etc.; in food-plants, as cereal grains, garden-vegetables, etc., and in ornamental plants, as roses, dahlias, pinks, etc. We can only give very briefly the principles of the process by which these extreme modifications are produced, referring the reader to works specially devoted to this subject for more complete accounts.

223

Let it be borne in mind, then (*a*), that inheritance is not only from the immediate parents, but from the whole line of ancestry. The inheritance from the immediate parents is, doubtless, usually greater than from any other *one* term of the ancestral series—the effect on the offspring of any previous generation becomes, doubtless, less and less as the distance from the offspring increases—yet the *sum* of the ancestral inheritance is far greater than the immediate parental. Let it also be borne in mind (*b*) that true breeding from one form for many generations creates a fund of heredity in that form, and thus tends to produce fixity, rigidity, or permanence in that form.

FIG. 68.

Now, the method of producing artificial breeds, sometimes consciously, sometimes unconsciously, is, briefly, as follows: Suppose it be desired to obtain a variety of an animal, say a dog, having a certain character. We start from a common type, *a* ([Fig. 68](#)). If this type were allowed to breed naturally, the slight divergent variation of offspring represented by the radiating lines would neutralize one another by interbreeding, the individual differences would be “*pooled*” in a common stock, and the species would remain substantially constant. But if among all these slightly divergent varieties we

224

select one, *b*, which seems in the right direction, and ruthlessly destroy all the others (indicated by crossing them out by the circular line), and breed this variety, *b*, only, we shall get again a number of divergent varieties. It may be that the larger number of these will be backward, in the direction of the original type *a*, on account of the ancestral heredity in that direction, but some will again be in the desired direction. Let all the varieties other than the desired one, but especially the backward-going or reverting ones, be again destroyed, and the one kind only selected which seems to be in the right direction, viz., *c*. As we push the form thus from generation to generation in the desired direction, especially if we attempt to hasten too much the process, the resistance to movement—if I may use the expression—in that direction becomes greater and greater (shown by the decreasing distances between the successive points of divergence, *a*, *b*, *c*, *d*, etc.), and the tendency to reversion becomes stronger (shown by the greater number and length of the backward-going lines), until finally it is almost impossible to push any farther. We will suppose that *x* is such a limit. But if, now, we breed true on the point *x*, destroying the reversions or backward variations for many generations, we will gradually accumulate a fund of ancestral heredity on this point which increases with every added generation, until finally the tendency to reversion becomes small. The variety *breeds true* without further interference, or with only very general superintendence. Such a permanent variety is called a *race*. After a race is firmly established for a sufficient length of time, and the tendency to reversion is lost, it may itself become a new point of departure for the formation of new varieties or races, in the same or other directions. Thus, during even the brief history of man, have been formed races of the different domestic animals, and useful and ornamental plants, differing so greatly from each other that, if found in the wild state, they would unhesitatingly be called different species, or even in some cases different genera.

225

Now, if art can vary form so greatly, and in so short time, why may not Nature in limitless time? If art by artificial selection, why not Nature by natural selection? Nature is as rigid in selection and as ruthless in destruction: why may we not expect similar or even much greater results? The process is similar in the two cases—i. e., selection among varieties in offspring, only that the selection is natural instead of artificial, and the process is so slow that there is little tendency to reversion in the latter case. Suppose, then, we have a gradually changing physical environment, or climate. Among the divergent varieties of any species in each generation, those would be preserved which are most in accordance with the new climate, and the others would perish. This is natural selection, or survival of the fittest. Add to this the effect of the change in the organic environment. All species are modified by the changing physical environment; but these modified species again all affect one another in the competitive struggle for life, and the strongest or swiftest, or most cunning, survive (natural selection). Add to this, again, the struggle among the males for possession of the females—for reproductive opportunities—by which only the strongest and most courageous, or the most beautiful and attractive, leave progeny which inherit their peculiarities (sexual selection). Add to these, finally, *migrations*, voluntary among higher and involuntary dispersals among lower animals and plants, and the consequent mingling of faunas and floras—the migrations subjecting them to great change of environment, both physical and organic, and the mingling producing fiercer struggle for life—and we have in powerful operation many causes of modification. Add, I say, all these causes of modification together, and then make the process slow and continuous through unlimited time, and where is the limit to the degree of change? Commencing in any species, from any point of departure, there are formed first slight modifications which would be called varieties; then these modifications, continuing in the same direction, form races; these races by wider separation become species, and species in their turn become genera, etc. Comparing, again, to a growing tree, varieties are swelling buds; when they grow into twigs, they are species; when they branch again into different species, the branching stem becomes a genus, etc.

226

227

We have thus far spoken only of the various forms of one factor, viz., the Darwinian factor of selection, whether natural or artificial. We have dwelt upon this one, because the natural and the artificial processes are so similar, and the artificial is so controllable. But there are other factors in operation, in art as well as in nature. We have already spoken ([p. 73](#)) of other factors of natural change. We have shown how changing physical environment affects *function*, and function affects *form and structure*, and how these slight changes are integrated by heredity through many generations. We have

also shown how *use* or *disuse* increases or diminishes the size and change the form of parts, and these changes, also, however slight, are integrated by heredity. 228

Now, these factors are operative also in domestication of animals and cultivation of plants. No environment is so new and peculiar as domestication and cultivation. The soil and temperature in plants, food and housing of domesticated animals, tend to change form and structure of the offspring, although in a way which it is difficult intelligently to control, and thus are prolific of varieties from which to select. In fact, they often give rise to great and unexpected modifications, called sports, which form points of departure for new varieties and races. Now, in nature, not only are all these causes and f