THE

PHILOSOPHY

OF

NATURAL HISTORY.

By JOHN WARE, M.D.

PREPARED
ON THE PLAN, AND RETAINING PORTIONS, OF THE WORK OF
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PREFACE.

THE origin and purpose of the work upon which the present one is founded are explained in the following extracts from the Preface of its author.

"About fifteen years ago, in a conversation with the late worthy, respectable, and ingenious Lord Kames, upon the too general neglect of natural knowledge, his Lordship suggested the idea of composing a book on the PHILOSOPHY OF NATURAL HISTORY. In a work of this kind, he proposed that the productions of Nature, which to us are almost infinite, should, instead of being treated of individually, be arranged under general heads; that, in each of these divisions, the known facts, as well as reasonings, should be collected and methodized in the form of regular discourses; that as few technical terms as possible should be employed; and that all useful and amusing views arising from the different subjects should be exhibited in such a manner as to convey both pleasure and information.

"This task his Lordship was pleased to think me not altogether unqualified to attempt. The idea struck me. I thought that a work of this kind, if executed even with moderate abilities, might excite a taste for examining the various objects which everywhere solicit our attention. A habit of observation refines our feelings. It is a source of interesting amusement, prevents idle or vicious propensities, and exalts the mind to a love of virtue and of rational entertainment. I likewise reflected, that men of learning often betray an ignorance on the most common subjects of Natural History, which it is painful to remark."

"Upon the whole, the general design of this publication is to convey to the minds of youth, and of such as may have paid little attention to the study of Nature, a species of knowledge which it is not difficult to acquire. The knowledge will be a perpetual and inexhaustible source of many pleasures; it will afford innocent and virtuous amusement, and will occupy agreeably the leisure or vacant hours of life."

The book of Mr. Smellie, prepared in accordance with these views, was first published about seventy years since, and continued in use during the early part of the present century. In the year 1824, at the suggestion of my friend Mr. George B. Emerson, it underwent a variety of alterations, intended to adapt it for use in the school of which he was then the teacher. An Introduction was substituted for the first two chapters, "containing some very general views of animal and vegetable life, and a brief sketch of the structure and classification of the whole animal kingdom." Of the remainder of the work some chapters were omitted, some portions were re-written, and many passages were added; but it remained essentially the same.

Since its preparation, especially during the last fifteen years, the work has been extensively used in the schools of the United States, and has been re-published in Great Britain. At the request of the publishers a new revision was undertaken, in order to adapt it more perfectly to the present wants of education.

In the present edition the subjects of the Introduction have been much more fully treated. In the body of the work, the original plan has been still adhered to, but extensive alterations have been made, and most of the chapters have been prepared anew. These alterations consist chiefly in a more full consideration of those parts of the animal economy which relate to the external life of animals, and which are consequently closely connected with the study of their characters, manners, habits, and mental characteristics. Complete statements of physiological details were not consistent with the plan or the limits of the work, and a full scientific view of Physiology was therefore not attempted. The object of the book is not to teach Natural History, technically speaking,— a task the author would not have ventured to undertake — but to present such views of it as would be intelligible to the young student and to the general reader, and prepare them for, and lead them to engage in, a more extended study of the subject as it is presented in treatises more strictly scientific and in the works of Nature.

J. W.

Boston, August, 1860.

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THE PHILOSOPHY

OF

NATURAL HISTORY.

INTRODUCTION.

CHAPTER I.

GENERAL CHARACTERISTICS OF LIVING BODIES.

NATURAL HISTORY in its largest sense embraces a very wide field of investigation. It gives the history not only of animate but of all inanimate matter, and thus extends to the mineral as well as the vegetable and animal kingdoms. It includes an account of the form, size, color, and other sensible qualities of minerals; of their position with respect to each other; their arrangement and relations as forming parts of the globe; and their relation also to the living things which now inhabit or have inhabited it. It teaches the circumstances in which vegetable and animal differ from mineral substances. It describes their structure and powers; the conditions of their existence; the laws according to which their structure and organization are made to vary, and the relation to external circumstances which renders variation of structure necessary. It arranges the individuals of these kingdoms into groups, according to certain principles of classification. It gives each individual a place in this arrangement. It enters into the history of each one; investigates its structure, its mode of life, its relation to external nature; in short, it determines and describes in detail every particular which can illustrate the character of its existence.

It is manifest that no human industry can master this whole subject. It has accordingly been subdivided into many departments, and each department affords ample material for the investigation of a lifetime. But the minute details which occupy the attention of the professed naturalist, are not calculated to engage the interest of the general student, or to constitute a part of the preliminary education of the young. For these they have not the taste, nor the time. Their purpose is better answered by the study of what has been denominated the PHILOSOPHY OF NATURAL HISTORY, a more general method of presenting the same subjects. Its purpose, beside a similar consideration of the objects of inanimate nature, is to illustrate principles according to which plants and animals are constructed; the laws by which their existence is governed; the conditions under which they come into existence, continue their existence, and terminate their existence; and thus to exhibit the plan of creation and the designs of the great Author of Nature, as they are displayed in this portion of his works. The Philosophy of Natural History is indeed little less than a system of Natural Theology drawn from the history of nature, and in no way can the power and wisdom of the Creator be more clearly illustrated.

The purpose of the present work is to illustrate this subject chiefly in connection with the animal kingdom, and chiefly also with those portions of this kingdom in which animal life is exhibited in its highest and most perfect state. To attempt more than this, would open a wider theme than could be clearly or profitably treated. It is not its object to teach the details of natural history except so far as they are necessary to the illustration of principles; and the phenomena exhibited by the mineral and vegetable kingdoms will only be so far adverted to as they have some relation to the conditions under which animals exist, the functions by which their existence is maintained, the relations they bear to each other, and the character they severally manifest.

If a common observer were asked in what respect an animal differs from a stone, he would answer without hesitation that it differs in being alive. If the same question were put with regard to a plant, the answer would probably be the same. Supposing it to be then inquired how the plant is distinguished from the animal; the solution might seem more difficult. Very likely, however, it would be thought sufficient to say that the animal could feel and move, and that the plant could not.

In point of fact these answers are sufficiently accurate, as far as they go, and yet how few of those who would make them, actually comprehend in their full extent the meaning of the very terms in which they are expressed. Our familiarity with animal and vegetable life, and our constant habit of making the distinction between the bodies possessed of them, actually prevent our perception of the wonderful and mysterious character with which they are invested. Till the conditions under which a living thing exists are deliberately considered, it is impossible fully to appreciate how strange and interesting is the simple possession of life. It impresses us most forcibly when viewed in its connection with the ordinary laws of matter, and in those species in which its attributes are most variously displayed. Strictly speaking, life is as completely possessed by the lowest plant as by the highest animal; but we can best appreciate its wonderful character when we consider it in connection with ourselves.

When a man dies, his body is speedily decomposed. If the results of its decomposition are examined, it is found to have been made up chiefly of water, nitrogen, a little phosphorus, a little sulphur, some charcoal and lime, with a few other earthy and some saline ingredients. But there is nothing peculiar in the materials of which it is composed. They are elements which are constantly present in the universe about us, and which enter into the composition of a thousand other bodies. They have in themselves, separately considered, none of those properties which are found in the animal into whose composition they enter. Indeed, their original physical and chemical tendencies are actually at variance with the relation they maintain to each other as component parts of a living system; so much so, that if the mysterious bond of connection which holds them together be dissolved by death, they separate sooner or later from each other, in conformity with their original and inherent tendencies.

This mysterious bond is the Principle of Life. By its influence we are enabled to maintain our existence in the midst of agents which are constantly seeking our destruction. Our bodies are composed of elements which exist everywhere in the matter around us, but gathered into new combinations and moulded into peculiar forms. The tendency of the common laws of matter is to dissolve these combinations and destroy these forms. Fire, air, and water, the cold of winter and the heat of summer, are alike our enemies. We have a chemical composition of our own, — a temperature of our own, — a power of spontaneous motion of our own. We maintain them in spite of the chemical affinities, the temperature, and the mechanical influences of the bodies that surround us. Deprive us of life, and our resistance to all these tendencies is at an end. Our power of motion is lost, and we yield at once to the force of gravity which brings us to the earth; — our temperature falls or rises to that of the medium by which we are surrounded; — and the chemical laws of matter, sooner or later, resolve our bodies into their original elements.

We are so familiar with the spectacle of life in nature around us, as well as with the consciousness of our own existence, that we are apt to lose sight of what is most wonderful in animals and in ourselves. We wonder at the strange and curious chemistry of digestion; at the nice mechanism of the heart; at the beautiful adjustment of the eye and ear, and their adaptation to light and sound. The greater wonder is that we can exist at all in the midst of a material world constituted as it is, and governed as it is by fixed laws.

Consider these laws: of Gravitation, universal, unerring, inevitable. Governing an atom as it governs a planet. Ruling all bodies, at rest or in motion, by one immutable principle. Of Heat, no less absolute and irresistible, — always tending to distribute itself in certain regulated proportions to all substances, and in the accomplishment of its laws producing the most violent effects, cleaving rocks and tearing open hills. Of Chemical Affinity, extending its sway over the same substances as the preceding, but for purposes entirely distinct. By its agency solid bodies dissolving and disappearing in apparently inert and impotent liquids; airs changing into liquids and liquids into solids; fire springing up in the midst of water, and water increasing the intensity of fire.

The empire of these laws over matter in its ordinary state is constant. There are no exceptions to it. But existing in the midst of them, the animal sets them all at defiance. He moves in opposition to and independently of the law of gravitation. He resists the influence of that external heat which subdues everything else. He maintains a chemical composition inconsistent not only with the chemical attractions of the substances by which he is everywhere surrounded, but inconsistent even with those of the elements of which he is himself composed. This is the position which we maintain in the midst of creation, and there is no wonder in the creation greater than this.

This is the universal condition of animal life. It is most strikingly exhibited and most clearly illustrated in man and the higher animals, but essentially the principle is of the same character in all, and is displayed by similar phenomena. Still, though thus alike in this fundamental principle, animals differ indefinitely in secondary particulars. They exist in different states, under different circumstances. They live on a variety of food. They inhabit the air, the water, the earth. Some are exposed to continued cold; some to continued heat; whilst others are undergoing a series of vicissitudes from heat to cold and from cold to heat. This renders necessary an immense variety in structure. The animal that flies cannot be built like the animal that runs; nor the animal that runs like the animal that swims. The animal that breathes in air and the one that breathes in water must each have an arrangement suited to the medium in which it lives. The necessities of all as to food, climate, habitations, require modifications in bodily structure to fit them for the place they are designed to fill. This is the origin and final cause of the varieties in animal form.

The study of this subject lays open to us a prospect of the wonderful economy with which Nature manages her resources. Notwithstanding the wonderful variety of animal forms, the fundamental operations by which life is maintained are essentially the same in all. It is in secondary particulars that the variation chiefly takes place. "Nature," as was happily observed by a celebrated physiologist, "is prodigal of ends, but economical of means." She uses but few materials and few tools; but the works she accomplishes are almost infinitely diversified in form, in character, and in purpose.

The first and fundamental distinction among the objects of the material world is, then, between those possessed of life and those not possessed of life; the former including plants and animals, the latter all other bodies. But in order fully to comprehend the nature of this distinction, it is necessary to study more in detail the conditions under which these two classes of bodies are found to exist.

The first distinction is in the character of their structure and the mode of their origin. Living bodies are made up of a variety of parts peculiar in their texture, each of which exercises an office subordinate to the purposes of the whole individual. Other bodies are on the contrary either of a uniform structure throughout, or, if not so, the several parts of which they are composed have no peculiar relation to each other more than to other matter, and contribute nothing to the relations of the whole mass into whose composition they enter except to its size and weight. Their existence is a continued one. Their structure and forms remain very much as they were in their original formation. It is true that convulsions of nature have brought about some revolutions in them, and accidental causes of less importance frequently produce some minor changes. But through all, the powers and properties remain the same. Matter always gravitates, and its elements, however divided and disturbed, always maintain the same relations, combine in the same forms, in the same proportions, and according to the same affinities.

But while the universe of common matter is thus permanent, that of living matter is in a state of constant revolution. Bodies are constantly going out of existence and new ones as constantly coming into existence. Change is the characteristic law of the latter, as permanency is of the former. Both in the animal and vegetable world each individual has but a limited term of existence. It is produced, grows, flourishes for a while, and then dies and decays. Hence the necessity of that provision by which they may be regarded as successively created, namely, that each individual is the offspring of another individual like itself.

This is a very complete distinction. No substance not possessed of life is ever brought into existence in this way. It is true that new bodies in the mineral world are formed by the accidental aggregation of particles, or by the spontaneous combinations which are the result of chemical laws; but this is clearly something very different from the mode of production which takes place in living bodies. One stone does not produce another like itself; a crystal does not produce a crystal, nor one grain of sand another. There is nothing like the relation of parent and offspring.

Connected with this circumstance, namely, the relation of parent and offspring, is another, not less important, — the relation of sex. This, more or less perfectly exhibited, is found in all the subjects of both the vegetable and animal kingdoms. To the continuance of every species this distinction is necessary, either existing in separate individuals, as in most animals, or combined in the same, as in most plants. It is true that in some species, as in bees and ants, there is a race of neuters, which possesses the properties of neither sex; but it is probable that these are rather to be regarded as individuals imperfectly developed, than as originally deficient in the appropriate characteristics.

In the second place, living bodies differ as to the mode of their existence, insomuch as they are dependent upon other things beside themselves for the continuance of that existence. The matter of which their active parts are composed undergoes, with more or less frequency, an entire change. It is, in fact, only common matter endowed for a certain period with the powers of life, in consequence of being united to living systems. By the various internal operations constantly going on, part of this matter is expended, is sent out of the system. This loss must be repaired by the addition of new matter. Hence the necessity of nourishment to the support of life; hence the necessity of a regular supply, to everything living, of a certain quantity of food adapted in kind to the nature of the individual. This food is operated upon by the organs of the animal or vegetable, is assimilated to it, and its properties are modified until it becomes fit to enter into its composition. This is Nutrition, an essential process of living bodies, by which they are enabled to increase in size and strength, to modify the structure of their different parts, and to maintain them in a fit state for performing the offices for which they are designed. Minerals, on the contrary, have no such dependence; the matter of which they consist is always the same; they contain within themselves everything which is essential to their existence, and have, of course, no necessity for nutrition or growth. It is true that these substances sometimes increase in size, as happens with regard to stalactites, the deposition of crystals, and the formation of alluvia. But there is this marked difference between all such instances of growth and that of animals or vegetables: that, in the former case, it amounts to the mere juxtaposition of similar particles, *unchanged in their nature;* whilst in the latter, the particles are *changed in their nature*, and subjected to the operation of entirely new laws. In the former case, the growth depends upon a principle operating from without; in the latter, upon a principle operating from within.

In the third place, although in this way dependent on other substances for the necessary materials by which their existence is supported, living bodies, in another point of view, exhibit a species of independence of other matter. As has been already stated, they are removed, to a certain degree, out of the influence of physical and chemical laws; they are enabled to resist their ordinary operation by an inherent principle, and without this would speedily cease to exist. They depend upon the things around them for the materials for their support; but the power of altering the nature of these materials, and appropriating them to their own use, is peculiar to themselves. The functions of living systems are not only performed without the assistance of the physical powers of matter, but often in direct opposition to them; and the substances which are introduced into them lose to a certain extent their chemical relations, and are combined according to new laws, and for new purposes.

This power of *insulation*, possessed by living systems, is in no instance more strikingly evinced, than in the possession by many animals of a certain degree of vital heat, which they preserve under all circumstances, short of those which impair or destroy the texture of their parts. This degree of heat, — which in man is about 98° of Fahrenheit's thermometer, — continues always nearly the same. In some countries, in which the degree of cold is for many months in the year very much below the freezing point of mercury, men not only exist, but enjoy all the comforts of life. In some high latitudes, Europeans have been exposed to temperatures as low as — 50° or even — 60° of Fahrenheit's thermometer, that is, about 150° below the natural standard of animal heat, and have escaped every ill consequence. Many years since, the whole of two ships' crews wintered in 75° of north latitude in perfect safety, where the temperature of the air was, for many weeks together, almost constantly below — 30°, and where they became so accustomed to severe cold, that the atmosphere, when at zero, felt mild and comfortable. In one of the more recent arctic expeditions a still lower temperature was endured, not only with impunity, but with comparative comfort. On the other hand, in many countries men exist without difficulty under a high degree of heat. In Sicily, during certain winds, the thermometer has been observed at 112°, in South America by Humboldt at 115°, in Africa at 125°. But, for a limited period, much higher degrees of artificial heat have been borne without injury. Individuals have exposed themselves voluntarily to the air of ovens at temperatures from 260° to 315° of Fahrenheit's thermometer, without any great inconvenience, while water was boiling and meat baking in the same atmosphere. Life has even been maintained by some of the lower classes under circumstances still more extraordinary. In some hot springs in the island of Ceylon fishes have been found swimming about in water from 87° to 115°; in Barbary at 172°; in Manilla at 187°, and, according to Humboldt, they have been thrown up alive from a volcano with water at 210°. These facts show a power of resisting the operation of external causes, which is possessed by no substances except such as are endowed with life, and is, probably, possessed in some degree by all that are. For, although vegetables and the lower kinds of animals are not capable of resisting to the same extent the influence of heat and cold, yet they all show, in some measure, the existence of the same power. And in the most imperfect species, where there is no other evidence, this power is evinced by the fact that the individual freezes with greater difficulty before than after death, other circumstances being equal.*

The same principle is exhibited in the resistance which living bodies offer to the causes of chemical decomposition by which they are surrounded. This resistance ceases as soon as life ceases, and is consequently due to its influence. We are exposed while alive to the same heat and moisture which work so speedy a change upon us after death; the composition and texture of our bodies are the same. We resist their influence by virtue of the possession of the principle of Life.

This suggests to us, in the fourth place, another distinction of living substances, namely: that they all terminate their existence in death. By this event, the materials which entered into their composition are deprived of the bond that held them together and gave to them their peculiar form. They therefore separate, and retain only those properties that they possessed before becoming parts of a living system. Dust returns to dust, earth to earth. It is true that some of the parts of living bodies, both animal and vegetable, do not very readily undergo the process of decay. The bones, teeth, shells, and horns of animals; the trunks, branches, and roots of trees, retain, for an almost indefinite length of time, under certain circumstances, their shape

* In quadrupeds and birds the animal heat is generally greater than, whilst in animals of the inferior classes it is seldom very different from, that of the medium in which they live. The former are called warm-blooded, and the latter cold-blooded. In the former, the temperature is capable of but slight variation from external causes; in the latter, its range is pretty extensive, and it varies a great number of degrees. The temperature of a man plunged into cold salt-water at 44°, has been known to sink to 83°, and when exposed to a heated atmosphere, to rise to 100°; in other warm-blooded animals similar varieties have been observed. But the temperature of the viper, a cold-blooded animal, when exposed to a heat of 108°, rises to 92°, and when exposed to a cold of 10°, sinks to about the freezing point of water, showing at once an extensive range of temperature within which the functions can go on, and at the same time a decided power of resistance against any further alteration.

Eggs possess an analogous power. A new-laid egg, and one which has been frozen and thawed, being exposed in a freezing mixture together, the former will be some minutes longer in freezing than the latter. This has been ascertained by experiment. The same is true of the lower orders of animals and vegetables.

and substance. This, however, is owing, not to their continuing to possess life itself, but partly to the particular character of the texture of which they are composed, and partly to their protection, by accident or intention, from the influence of air, warmth, and moisture. Nothing like this takes place in other substances: they can be destroyed only by the action of some mechanical agent, which separates their parts, or by that of some chemical one, which alters their combinations.

There is still a fifth circumstance in which organized differ essentially from unorganized bodies. The properties which the latter possess, and the laws by which they are governed, are definite in their character. Uniform causes produce uniform results; and these results are capable of being calculated and measured. It is widely different in living bodies, so far at least as we are able to analyze the conditions under which they exist. This peculiarity is most distinctly exhibited among the higher classes of animals, but is to be everywhere recognized. Individuals of the same species differ indefinitely as to the mode and degree in which they are influenced by external causes. We can predict of any inorganic body, that it will be always affected in the same way by the same agents. We cannot predict this of any organic body; on the contrary it is hardly ever influenced in precisely the same way at different periods by the same cause.

A remarkable result of this peculiarity is the formation of habits. All living things are believed to be capable of this. No others are capable of it in the slightest degree. It is one of the most striking differences between the two great divisions of natural objects. It is exhibited in a variety of ways. The life of many, both plants and animals, is a history of the formation of habits, some of which are confined to, and terminate with, the individual, others are transmitted to the offspring. Thus the physical character and even structure of plants are altered by climate, by modes of cultivation, by kinds of food; and not only is the same true of animals, but it goes even further, and we see changes formed and transmitted, so to speak, in their instincts, their intellect, and even in their passions and propensities. Hence it is in the subjects of organic life alone that we discover the existence of a proper individuality.

There are other phenomena which further illustrate the distinction between the organic and inorganic modes of existence. Animals and vegetables are capable of passing into a condition in which there is a suspension, for a time, of many and sometimes of all their functions, which after a time they resume. Of this we have examples in the daily sleep of animals, and the torpid state into which many animals and almost all plants fall during certain portions of the year. There is, in these cases, an intermission in the exhibition of those properties by which the individual is particularly characterized. Nothing truly analogous to this takes place among mineral substances.

CHAPTER II.

CHARACTERISTICS OF ANIMALS AS DISTINGUISHED FROM PLANTS.

Practically there is not often any difficulty in distinguishing an animal from a vegetable. But when it is attempted to point out the philosophical or essential principle in which their difference consists, the task is not so easy. In fact, there does not appear to be any such principle lying at the foundation of the distinction between animals and plants, that there is between organized and unorganized bodies, namely the principle of life. There are certain close points of resemblance between the composition, the structure, the functions, and the conditions of existence of animals and vegetables, which do not exist between either of them and minerals. So much is this the case, that some writers, among whom was the celebrated Buffon, have believed that there is no exact boundary, but that so close a resemblance of characteristics exists between those living at the two extremes, that individuals possessing the peculiarities of animal life in the lowest degree, are not essentially different from the plants which possess them in the highest.

It is probable, however, that the difference between these two classes of bodies is essential and fundamental; and it is worth while to enter somewhat into the examination of it, not simply on account of its intrinsic importance, but because such an examination will serve to illustrate not only the differences between animals and vegetables, but the nature of their life, the tenure and conditions of their existence, and the general character of the structure and functions by which their existence is originated and maintained.

It has been remarked that a vegetable may be compared to an animal asleep, since it exercises, throughout its whole existence, just those functions, and no others, which an animal continues to exercise during sleep. "Sleep," says Buffon, "which *appears* to be a state purely passive, a species of death, is, on the contrary, the original condition of animated beings, and the very foundation of life itself. It is not a privation of certain qualities and exertions, but a real and more general mode of existence than any other." This remark is more ingenious than just. It is founded on an imperfect view of the nature of sleep. The essential quality of this state is that it implies the suspension of certain functions during its continuance, which may be exercised at other times. A living body cannot justly be regarded in a state of sleep, which is in the actual performance of all the functions of which it is capable. Strictly considered, the remark means only this: that, during sleep, animals *continue* to perform only those functions which are absolutely necessary to the existence of a living thing; that these functions are those which vegetables *always* perform; and that there is consequently an analogy between an animal, when its peculiar functions are suspended, and a vegetable in its ordinary state of existence. This analogy, though fanciful in the terms in which it is expressed, is founded upon the real differences between the two forms of life; and vegetable life, though not a more real, may justly be regarded as "a more general mode of existence" than animal.

The animal life seems to be, in fact, superinduced upon the vegetable. The fundamental operations of living systems — those by which they are brought into, and continued in existence — are the same in both. They have been called, by way of distinction, the vegetable or organic functions. Animals perform, in addition to these, certain others peculiar to themselves; chiefly reducible to the two, sensation and motion; and these are denominated the animal functions. It is in the structure by which, and the mode in which, these several functions are performed, that the real distinction between the two kingdoms is to be sought; and although there may be certain individuals in each, with regard to which it is difficult to detect the details of the distinction, there is reason to infer, from the well-established uniformity of the laws upon which the creation proceeds, that they exist.*

We find a marked difference between animals and vegetables, as to the manner in which the functions common to both are performed, as well as in the possession by the former of certain others, which are not possessed by the latter. To both, as already remarked, a male and female parent is necessary. In the vegetable, the new individual is produced by means of a seed; in the animal, of an egg; for though many animals are viviparous or produce their young alive, the process is in them essentially the same as in the oviparous, differing only in the circumstance that incubation takes place within the body of the mother.

The seed, then, corresponds to the egg, but there is a difference in the mode of their development. The organs of the animal are formed within the egg, and it is not extruded till it is capable of performing all those functions which are essential to its life. During this process it is nourished by the contents of the egg, or by materials derived from a subsequent continued connection

* A doubt has sometimes arisen in regard to certain species, — whether they should be considered as belonging to the vegetable or animal kingdom. But the existence of this doubt does not involve any question as to the essential distinction between these kingdoms. In fact, the very controversy involves the recognition of their fundamental difference. It may be further observed that this doubt has always existed with regard to individuals at the very lowest boundary of the two kingdoms. Now it is in the highest forms at which the two ever arrive that we are to seek for the distinction between them, and here we readily detect sufficient evidence that this distinction is an essential one. If we cannot detect this among the lower and more obscure forms, we have reason to infer, not that it does not exist, but that from a deficiency in our means of observation it eludes the scrutiny.

with its parent. In the seed, on the contrary, although it contains the germ of the future plant, and the process of development begins within it, yet it mainly takes place without, and it is not till after it has sent its roots into the earth, and its stem into the air, that the organs necessary to its future existence are constructed.

Plants and animals are equally dependent upon food, for the continuance of existence and the performance of their functions; but they differ from each other in the manner in which it is done. In the plant it is effected by means of roots. These are usually distributed under the earth, but sometimes they float loosely in the water, are attached to other plants, or in some rare cases are only exposed to the air. In animals, on the contrary, food is received into an internal cavity, and undergoes the process of digestion, before it is admitted into the circulation, and applied to the nourishment of the system. The difference then is, that plants absorb their food by an external surface, whilst animals absorb it by an internal surface.

They differ also in the nature of their food. Animals derive their nourishment chiefly, if not exclusively, from matter which has been already organized, either in some vegetable or animal system. Plants, on the contrary, derive it chiefly, if not exclusively, from elementary matter, or matter which is not in an organized state. It is true that they flourish best in a soil which contains the remains of vegetables and animals; but it is only after these remains have lost their peculiar structure, and are in a state of decomposition, that they answer this purpose. A plant cannot subsist upon animal or vegetable substances as such, nor an animal upon simple unorganized matter.

They differ again in their chemical composition. To vegetable substances three elements are principally necessary, — hydrogen, oxygen, and carbon. Animals in addition to these require a fourth, azote or nitrogen. It is true that there are some important vegetable substances into whose composition nitrogen enters, and some animal ones into whose composition it does not; and that in addition to these principal ingredients there are certain secondary ones which are more or less constantly present in both, such as salt, lime, sulphur, phosphorus, iron, and some others.

Still the predominance of nitrogen in animal substances is a distinct and important peculiarity, and not only influences their textures during life, but the results of their decomposition after death.

They differ, also, in their relation to the external atmosphere. The influence of the air is necessary to the existence of each, but in a different way. The lungs or other breathing organs of animals *give out* carbonic acid as the result of the function of respiration. The leaves, which are the breathing organs of plants, *take in* carbon as the result of their function of respiration.

They differ again as to the manner in which their circulation is performed. Both are supported by means of a fluid which is distributed to every part,—the sap and the blood. But the mode of distribution differs. The vessels of plants are cylindrical; they proceed parallel to each other from their origin in the root to the extremity of the branches, of the same size, without division, and, as some assert, without intercommunication. In animals, on the contrary, the vessels begin in large trunks, often from some central organ, or heart; are constantly subdivided, and diminish in calibre as we approach their extremities; are not parallel to each other; and are frequently intercommunicating through their whole course. This at least is true of all those in which the arrangements of the circulation are capable of a careful examination.

Another important difference is in the degree of permanence of the organs by which their principal functions are performed. In plants, no matter what their age may be, these endure but for a single season. Not only the leaves, but the circulating vessels, which exist in the inner layer of the bark and in the alburnum, or external layer of wood, are annually renewed. In animals, on the contrary, all the important organs are permanent, and endure as long as the individual.

This depends upon a difference in the laws according to which nutrition and growth take place in the two kingdoms. In each, the several organs require renovation and repair. In vegetables this is effected by the virtual death of the organ. It ceases to have any connection with the functions of the plant, even where it does not, as in the bark and wood of trees, undergo an actual separation. In animals the organ is not removed as a whole. It does not lose its shape, its texture, or its vital connection with the individual. Its separate particles are removed one by one and new ones substituted in their place, so that it is probably renewed many times in the course of a year; but the principle upon which this is done differs essentially from the corresponding one in plants.

The final cause for this difference, as observed in plants which have a long continued existence, is at once wonderful and beautiful. Were the organs of plants renewed, like those of animals, by an interstitial growth, never increasing in size and strength after arriving at maturity, they would not be able to support the growth of many years. The parts by which nutrition is carried on form a thin cylindrical cavity, a mere shell, quite inadequate to support the weight of the branches and leaves. But year by year a new growth is formed around it; the old wood ceases to live, but continues its mechanical connection in order to give support and strength to the trunk, of which it afterward forms a part. By this deposit of new matter, as the wood is thrown inward the bark is thrown outward, and thus an annual increase of wood is insured, to support the corresponding increase in the amount of branches, leaves, and fruit; meanwhile the bark dries, cracks open, and forms a hard, rough, and irregular crust on the outside.

Hence it is that animals arrive at a limited size in a limited time, and for the greater part of their existence do not grow at all. The bones, when they have arrived at the hardness of mature life, cease to increase in bulk, and the other organs not being renewed every season, as in plants, gradually lose the perfectness of their texture and become unable to perform their functions. Some vegetables, as trees, on the contrary, have no such definite term of existence. They may live almost indefinitely, and grow as long as they live, because their organs are wholly new every year, and because those parts which correspond to bones increase in size and strength, in proportion to the amount of leaves and branches which they have to support.

Even, then, in those functions which are common to both, vegetables and animals differ from each other. But beside this there are certain others possessed by animals which vegetables do not possess at all. These are sensation and voluntary motion.

By means of sensation, the individual is informed of the existence of other things beside himself; of their qualities, and of their relations to himself; he is rendered capable of pleasure and pain; in short, sensation is the indication of a conscious existence. By the power of voluntary motion, he is enabled to move the different parts of his body upon each other, and to move the whole body from place to place.

To the exclusive possession of these powers by animals, there are apparent exceptions. Some vegetables do move from place to place with as much apparent volition as certain animals; whilst there are some animals as immovably fixed to one spot as vegetables by their roots. There are also plants which exhibit motions seemingly as voluntary as those of some of the lowest animals, and for as definite a purpose. The sensitive plant is a striking example of this kind. 'The slightest touch makes its leaves suddenly shrink, and together with the branch bend down towards the earth. But the moving plant, or *Hedysarum gyrans*, furnishes a more astonishing example of vegetable motion. Its movements are not excited by the contact of external bodies, but solely by the influence of the sun's rays.* Its motions are confined to the leaves, which are supported by long flexible footstalks. When the sun shines, the leaves move briskly in every direction. Their general motion, however, is upward and downward. But they not unfrequently turn almost round; and then their footstalks are evidently twisted. These motions go on incessantly, as long as the heat of the sun continues. But they cease during the night, and when the weather is cold and cloudy. The *Dionæa muscipula*, or Venus's flytrap, a plant of Carolina, affords another instance of rapid vegetable motion. Its leaves are jointed, and furnished with two rows of strong spines. Their surfaces are covered with a number of minute glands, which secrete a sweet liquor, and

* Sir J. E. Smith states that light is not necessary, but that only a warm, still atmosphere is required to produce this phenomenon in perfection.

allure the approach of flies. When these parts are touched by the legs of the fly, the two lobes of the leaf instantly rise up, the rows of spines lock themselves fast together, and squeeze the unwary animal to death. If a straw or pin be introduced between the lobes, the same motions are excited.'

The common barberry is another instance to the same effect. When its flower is fully expanded, if the inside of one of the filaments of its stamens be just touched by a pin or a straw, it contracts instantly, and throws its anther forward with some force against the stigma.

'When a seed is sown in a reversed position, the young root turns downward to enter the earth, and the stem bends upward into the air. Confine a young stem to an inclined position, and its extremity will soon assume its former perpendicular direction.' The roots of a tree growing on dry or barren ground, in the neighborhood of that which is moist or fertile, become larger, longer, and more full in that direction than in any other, as if extending themselves to obtain the nourishment which can there be afforded them. If we twist the branch of a tree, so that the under surface of the leaves shall come uppermost, they gradually turn upon their footstalks till the proper side is exposed to the rays of the sun. This they will do repeatedly, until they have become injured by the exertion; and if the leaf be confined, so that it cannot resume its natural position, its stalk will become twisted by the effort to accomplish it. The sunflower, the leaves of the mallow, and some other plants, generally turn their faces towards the sun. The tendrils of plants, on the other hand, move towards the shade, in whatever direction it may be. In a green-house, if exposed to the morning light, they direct themselves towards the west, at noon to the north, and at night to the east. They are also attracted by opaque bodies.

Instances of a similar nature are afforded by what has been denominated the sleep of plants. The leaves of many are folded together during the night, and droop as if dying. In some instances they are so arranged, when in this state, as to serve as a cover to the flowers or young fruit. The flowers of other plants follow the same law, and close at the approach of night, for the apparent object of shelter and protection.

In many of these instances the motions so nearly resemble those of some of the lower animals, that it is not easy to say wherein they differ in principle, although in such cases there is no danger of supposing the plant to be an animal. Probably the principle of distinction is this. In the plant, the phenomena are purely local, and do not imply any connection with, and consciousness of, the individual considered as a whole. In the animal, on the contrary, we have reason to believe that the whole individual experiences a degree of consciousness. Touch a stamen of the barberry and a leaf of the sensitive plant, and that stamen and that leaf contract. But touch the petals of the barberry, and the stamen will not contract; touch the stem of the sensitive plant, and the leaf will not. On the contrary, touch any part of an oyster whose shell is open, and the muscle which closes the shell, though at a distance, contracts and closes it. So when the arms or feelers of a snail are extended, touch any one, or touch any part of the body, and they will all be contracted.

The inference is, that in an animal there is some central power or principle giving to it a unity of being and purpose, which is wanting in a vegetable. This is called the sensorial power. It is that directing and controlling principle which receives all impressions from without, and from which proceed all the voluntary motions. Its residence is in the brain and nervous system. Its powers become less complete and extensive as we descend from man to the lower animals, in proportion as the brain and nervous system become less perfect; but, go as low as we will, traces of it are still to be found.

CHAPTER III.

GENERAL STRUCTURE OF ANIMALS.

HAVING thus endeavored to illustrate the relation which animals bear to other bodies, and the peculiarities by which their mode of existence is characterized, it is our next object to inquire how their existence is maintained.

This will be done most clearly by an examination of the subject in connection with man, the animal in whom all the purposes of life are carried out on the largest scale and in the most complete manner. We call him the most perfect of animals. Not that the structure of the lowest is less perfect in itself than that of the highest. Each species is adapted equally well to its own end. But the end of his being is higher in man; its purposes are more numerous, varied, and elevated; we place him, therefore, at the head of the creation, and yet in the lowest animals the purposes of their existence, such as they are, are carried out with as much skill and by as perfect an apparatus as in him.

The life of animals is maintained, as has been already stated, by two sets of functions; one set common to all living things, by which the life of the individual is maintained; and another set by which the individual maintains a connection with the external world. The former are called the organic functions, or functions of organic life; the latter, the animal functions, or functions of animal life. The former are in man wholly subsidiary to the latter. It is the animal functions which make him what he is. He digests no better, he breathes no better, he circulates no better than the lowest of his class. It is in the combined perfection of sensation, motion, intelligence, and speech that he excels them all.

As the distinctive character of man depends upon the mode in which these functions are performed, so his external form is the expression of that character. The organs of intellect, of sense, of motion, of voice, constitute this form. As the basis or support of it, there is a bony structure or skeleton, which will be first described.

The bones of the human body are divided into those of the head, trunk, and extremities.

The head includes the *cranium*, or skull, and the face. The skull is a large bony cavity, composed of several wide, thin, and arched bones, united together by what are called sutures. It contains the brain, and gives passage to the spinal nerve through a hole situated in its lower part, where it proceeds from the brain, and goes to the backbone. The face is formed of the upper and lower jaws, and of the organs of seeing, smelling, and tasting. The bones which form the basis of these organs, are very numerous and difficult to describe. When taken together they give the general shape and configuration of the countenance.

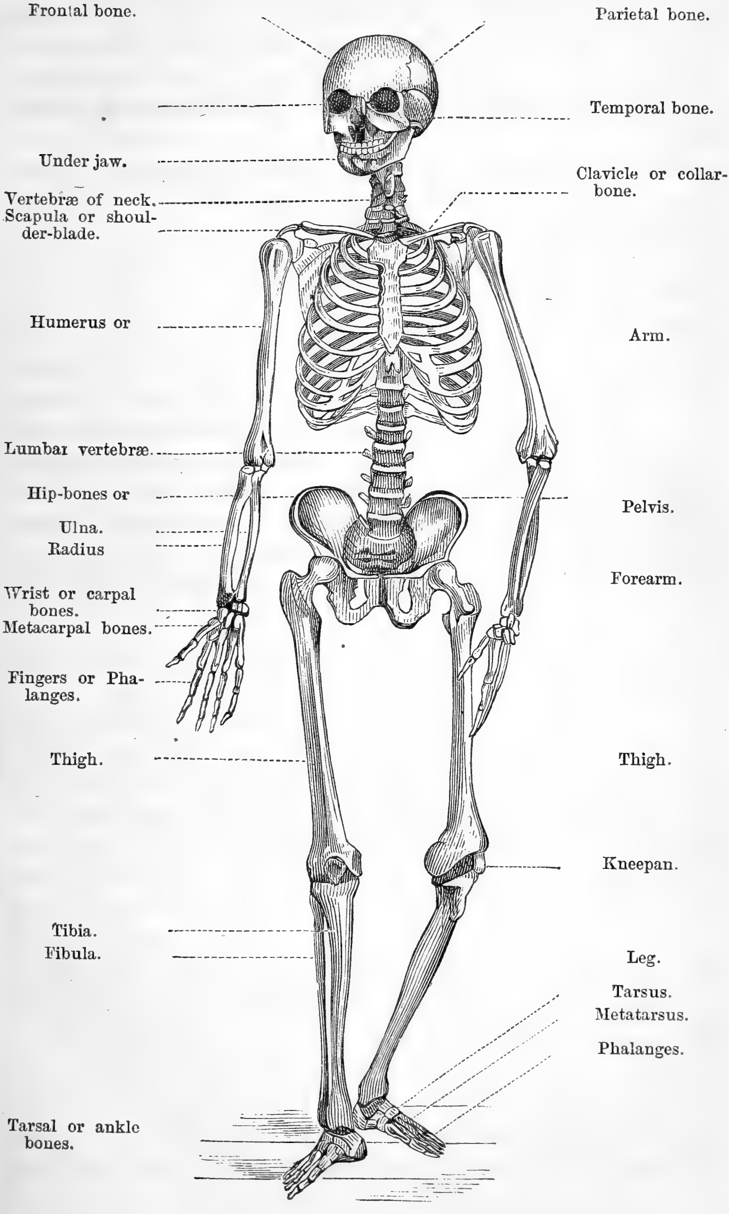
The head is placed on the top of the backbone, and is capable of a variety of motions upon it. The backbone is the main support of the trunk of the body, and is composed of twenty-four distinct bones called vertebræ, placed one above another, so as to form a kind of pillar or column. The body of each vertebra consists of a solid cylindrical piece of bone, and this is united firmly to those contiguous to it, above and below, by strong and elastic cartilages. The body of the vertebra is solid; but behind it, and on each side, are projections of bone, called processes, which are arched over and connected together in such a manner as to form a canal from one end of the spine to the other. This canal contains the spinal nerve or marrow, and between the vertebræ are holes through which branches are sent out to the different parts of the body. (Fig. 1 and Fig. 2.)

Fig. 1.

Vertebra.

Seven of the vertebræ belong to the neck, twelve to the back, and five to the loins. They are called respectively the cervical, dorsal, and lumbar vertebræ. They increase in size from above downwards, so that the lumbar vertebræ are much larger, thicker, and stronger than those of the back and neck. To the dorsal vertebræ are affixed twelve ribs on each side, which arch over forwards, and are joined to the sternum or breastbone by means of cartilage or gristle. In this way they form the cavity of the thorax or chest, which contains the heart and lungs. This cavity is terminated below by a muscular membrane, called the diaphragm or midriff, which extends from the edges of the lower ribs, and stretches across to the backbone, so as to form a complete curtain or division between the chest, and the abdomen which lies below it. This is another important cavity, usually called the belly, containing the stomach, liver, spleen, intestines, and other important organs. It is formed below by four bones attached to the lower end of the back, which spread out

Fig. 2.
SKELETON OF MAN.



and constitute a sort of basin, called the pelvis. This serves as a solid basis to support all the heavy organs contained in the abdomen, which is protected before and at its sides only by skin, fat, and muscles, and has no bones, except below and behind.

The limbs of man and other animals are called their extremities. The arm, or upper extremity, is composed of the shoulder, which has two bones, the collar-bone and shoulder-blade, by which it is connected with the trunk; the arm, which has only one bone, long and firm, extending to the elbow; the fore-arm, which has two long bones, parallel to each other, extending from the elbow to the wrist; the wrist, having eight small and irregular bones; and the hand, on which there are four fingers, each with four bones, and the thumb with three. These bones are united together, so as to form movable joints of various degrees of flexibility and power, by means of firm substances called ligaments. The surfaces which move upon one another are covered by a smooth, polished substance, cartilage, always lubricated by a fluid like the white of eggs, that renders all their motions easy and free from impediment.

The lower extremities are constructed in a similar manner. The thigh-bone, the largest and strongest bone in the body, is connected above with one of the bones of the pelvis, by means of a large, round head, which is received into a socket of corresponding size, and thus forms the hip-joint. Its lower end, together with the kneepan and one of the two bones of the leg, contributes to form the knee-joint. These last are parallel to each other, and extend from the knee to the ankle. The ankle is composed, like the wrist, of a number of small bones, of which there are seven, one of them projecting behind to form the heel. The toes have the same number of bones as the fingers and thumbs, but are shorter and less capable of free and extensive motions.

These different bones are covered by muscles, fat, and skin, which constitute the principal soft parts of the body. The muscles are fibrous organs, which, attached to the bones generally by tendons, by their contractions put the bones in motion, and thus originate all the movements of which we are capable. They act, in fact, like cords attached to levers, and operate according to strict mechanical principles.

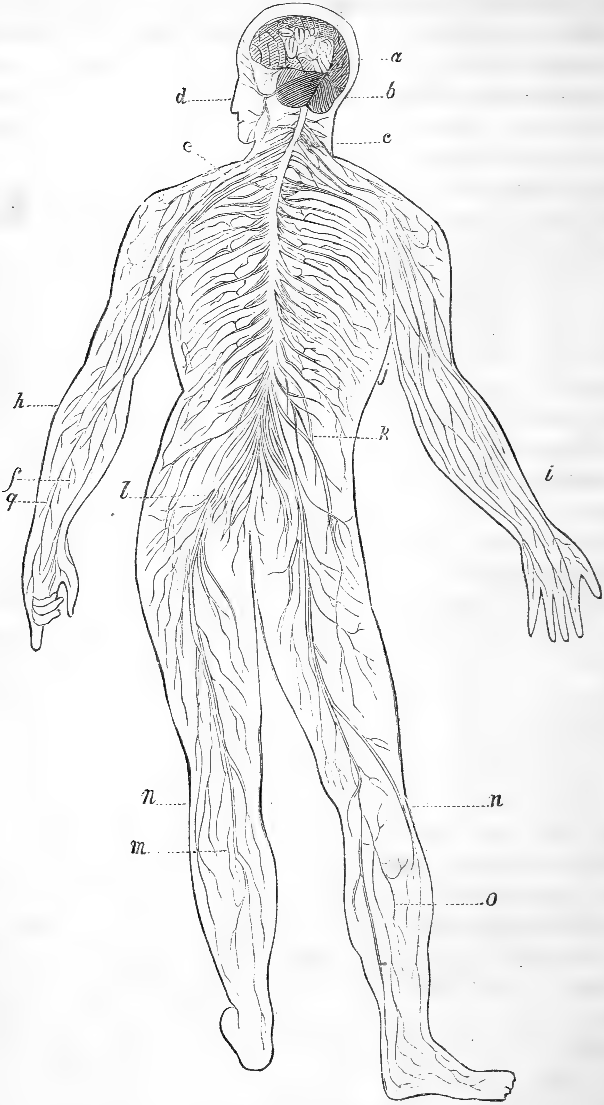
The organs, by whose operation the digestion of food, the circulation of the blood, and the other important functions are performed, are contained in the three cavities of the cranium, the thorax, and the abdomen, which have been already cursorily described. We proceed to a consideration of these several functions, beginning with those of the brain and senses.

The brain, in man, is the grand centre of sensation and perception. It is the instrument through which the mind maintains its connection with the body; and this connection is extended from the brain to the other parts by means of nerves. The brain is a large organ, of a peculiar texture, occupying the whole of the cavity of the cranium, and consisting of several distinct parts. Several pairs of nerves proceed from it through different apertures in the skull, and are distributed to the parts about the head, to convey to them the powers of sensation and motion. But besides these, there is another large single nerve passing down into the canal formed by the vertebræ, already described, and supplying the greater part of the body and limbs. (Fig. 3.)

Through the nerves, impressions are transmitted from all parts of the body to the brain; and on the other hand, all the acts of the will produce an effect upon the different organs by their means. The nerves are necessary to the exercise of the senses (which in man are five: seeing, hearing, smelling, tasting, and feeling); for if the nerve going to the organ of either of these senses be injured, the mind no longer receives any impression from that sense, as happens in the disease of the eye called *gutta serena*, or *amaurosis*. And if the nerve going to any of the limbs be destroyed or obstructed, both sensation and power of motion in that limb are either destroyed or suspended. This happens when a limb, from long-continued pressure upon it, is said to be asleep; as, in sitting for some time in one particular position, the nerve going to one of the legs is pressed upon, and the connection with the brain being thus interrupted, the consequence is a loss of feeling and motion, which is sometimes so great as to cause the person affected to fall down, on attempting to walk.

The senses, taken altogether, are more perfect in man than

Fig. 3.



NERVOUS SYSTEM IN MAN. — In this figure is represented the general distribution of the brain and nerves throughout the body.

a, the principal portions of the brain or cerebrum, called the hemispheres ; *b*, a smaller distinct portion, — the cerebellum; *c*, the spinal nerve which passes down the back through a canal formed by the vertebræ; *d*, nerves of the face; *e*, a network or collection of nerves to supply the arm; *f*, *g*, *h*, *i*, nerves of the arm; *j*, of the ribs; *k*, of the loins; *l*, of the hip and thigh or the sciatic; *m*, *n*, *o*, of the leg.

in any other animal. Yet in each of them, individually, he is probably excelled by some particular species. Thus, in sight, he is exceeded by the vulture and eagle; in hearing, by the greater number of rapacious quadrupeds; in smell, by the dog; in taste, by a great many animals; and in nicety and delicacy of touch and feeling, by most insects.

In performing the function of digestion, the food is in the first place taken into the mouth, mixed with the saliva, and ground into a kind of paste, by the action of the jaws and teeth. It is then swallowed through a long muscular canal, the œsophagus or gullet, which passes through the thorax behind the heart and lungs, near the backbone, and is conveyed into the stomach, through its upper or cardiac orifice. This is an irregularly-shaped muscular bag or sack, situated in the upper part of the abdomen, at the spot usually called the pit of the stomach. It is capable of great distention or contraction, according to the quantity which is put into it. In the stomach, the food is acted on by a peculiar fluid, called the gastric juice. It has no remarkable sensible qualities, and is nearly tasteless and destitute of odor; but its operation upon the substances exposed to its influence is very decided and powerful. They are gradually reduced, of whatever kind they may be, to one homogeneous mass, called *chyme*, of a grayish color, and of a consistence like that of thick cream. This operation being completed, the chyme passes out of the stomach, by its lower or pyloric orifice, situated towards the right side, into the intestines, which form a long canal, and, taken together, are many times longer than the body.

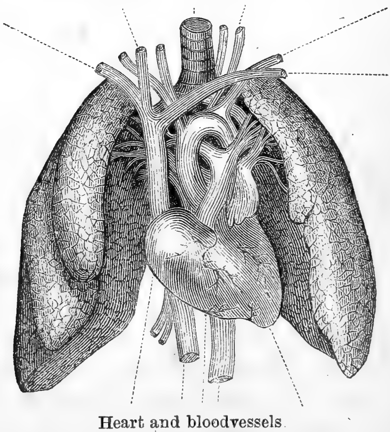
In the intestines, the chyme is subjected to the action of the bile and pancreatic juice. The bile, or gall, is a brown-colored, viscid, and very bitter fluid, prepared by the liver, a large organ on the right side, just beneath the ribs, and collected into the gall-bladder, where a part of it is reserved for use. The pancreatic juice resembles very nearly the saliva in color and appearance, and is prepared by the pancreas, an organ situated just below the stomach. These two fluids, the whole of whose office is only imperfectly understood, are mixed with the chyme, which is then separated into two parts. One of these is a thin, milky fluid, called *chyle;* the remainder consists of those portions of the food which are not fit for the nourishment of the system, but are rejected and thrown out of it, as useless. The chyle is gradually absorbed by capillary vessels, called the lacteals, opening into the intestines through nearly their whole course, and conveyed into a vessel called the thoracic duct. This duct ascends from the abdomen along the back into the thorax, and there empties its contents into the vein coming from the left arm, or left subclavian, where the chyle is immediately mingled with the mass of blood, and enters with it into the circulation. The chyle is essentially of the same composition from whatever substance it is prepared, when the digestion is perfect. Some kinds of food, however, are capable of furnishing a larger proportion of it than others: this is the case with animal food, of which it takes a smaller quantity to supply the system with nourishment, than of vegetable. Animal substances are not required to undergo so great a change in their conversion into chyle, as vegetable; and hence it is observed, that in animals subsisting on vegetables, the digestive organs are more various, extensive, and complicated, than in those which are carnivorous.

The chyle, being mixed with the blood, becomes a part of it, although it is not known where or how its change from the white

Fig. 4.

Windpipe and bloodvessels.

Lungs.



Lungs.

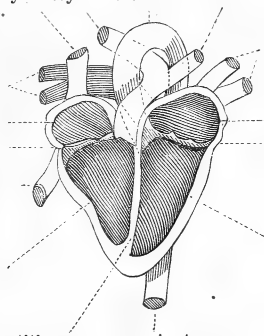
Heart and bloodvessels.

Contents of the thorax or chest in man: the windpipe or trachea, lungs, heart, and bloodvessels.

to the red color is effected. It is then circulated throughout the body, by the heart, the arteries, and the veins. The heart is a hollow muscular organ, the main-spring of the circulation; the arteries are long cylindrical canals or pipes, carrying the blood from the heart to the different parts of the body; the veins are vessels of a similar form and structure, bringing the blood back to the heart, after it has gone the round of circulation.

The relation of the several parts of the heart to each other is illustrated in the following diagram. It supposes the organ to be cut open, and its cavities with their connecting valves to be displayed. The relative size and position of the parts are varied from nature in order to present a more intelligible view of their mechanism.

Fig. 5.



The heart in man is a double organ; that is, it consists of two complete and distinct organs, united together into one mass, but performing their functions without interference or connection. These two parts are called the right and left sides of the heart; and each has two distinct cavities, called auricles and ventricles. The right side of the heart receives the blood from the body at large, and sends it to the lungs; the left receives it from the lungs, and sends it to the body. The heart is of a conoidal shape, situated in the thorax, just within the sternum, a little inclining to the left side. It is, however, placed with the apex, or point of the cone, extending downwards and to the left, so that it touches the ribs at the spot where the beating is felt, and hence is often supposed to lie entirely on the left side. The main body of the heart is composed of the two ventricles, which are strong muscular cavities, the left far more so than the right; the auricles are situated around the base of the organ, seeming rather to be loose appendages than constituent parts of it.

We shall begin with the course of the blood at the point where it receives its new supply from the chyle. The subclavian vein, after uniting with the vein from the other arm and the veins coming down from the head and neck, conveys its blood immediately to the right auricle, where it meets with that brought from the lower parts of the body. The two trunks which bring the venous blood in this way to the heart, are called the descending and ascending venæ cavæ. They pour their blood into the right auricle, which contracts, and expels it, through an opening for that purpose, into the right ventricle. This opening is guarded by the tricuspid valves, which prevent the flowing back of the blood, by completely closing the passage. When the ventricle has become distended, it contracts in its turn, and the blood, being prevented from returning to the auricle, is thrown forward into the pulmonary artery, which carries it to the lungs. This passage is also guarded by valves.

At the time of its passage through the right side of the heart, the blood is of a dark bluish red or purple color, approaching almost to black. It is generally called black blood, and is neither fit for circulation in the vessels, nor for the nourishment of the different parts. In this state it is sent to the lungs. These fill up all that part of the cavity of the chest not occupied by the heart, which they nearly surround upon all sides. They consist principally of a collection of blood and air vessels, and are constantly supplied with air, which is drawn in through the windpipe, and distributed to every part of them. The blood is circulated throughout their substance, by the branches of the pulmonary artery, and is, in its course, exposed to the influence of the air. By this means, its color is changed to a bright crimson or vermilion, and it becomes fit for the purposes of life.

It is now brought back to the left side of the heart, by the pulmonary veins, and passes through the left auricle and ventricle, in a manner similar to that which has been already described with regard to the right side. The left ventricle, from its superior size and strength, gives to the blood a more powerful impulse than that which it receives from the right. This is necessary, because it has a wider and more extensive course to traverse. From the left ventricle, it is thrown into the aorta, the great artery which supplies the whole body with blood. This artery ascends from the heart for a short distance, arches over, sends branches to the head and arms, and then descends behind the heart, and distributes branches to the other parts of the system.

The branches thus distributed throughout the body are subdivided again and again to an almost inconceivable degree of minuteness, and finally terminate in a system of vessels called *capillary* vessels. These pervade every part; and the blood, after passing through them, enters into another set of vessels, the veins, which gradually collect together and enlarge in size, till they terminate, as has been before remarked, in two large trunks at the right auricle of the heart. In the capillary vessels, the blood undergoes a change in its qualities, precisely opposite to that which takes place in the lungs. It becomes, from a bright red color, of the same dark red which it was described to possess when passing through the right side of the heart. This change is presumed to proceed from the office which the blood performs in the nutrition of the body during its circulation, and by which some of its elements are abstracted from it, and combined with the texture of the organs.

This office, namely, the nutrition of the several parts, consists of a double operation. By the first, the particles of an organ which have become unfit any longer to enter into its composition, are taken up and carried back into the circulation. This process is called ABSORPTION; by the second, called NUTRITION, new particles are substituted in their place. In this way the injury sustained by the wear and tear of the system is constantly repaired, and each part is kept fit for use.

The particles which thus go back into the blood, and circulate with it, are not, however, retained in the system for any length of time. They are speedily separated by a process called EXCRETION, and are carried off chiefly by the skin, the lungs, and the kidneys.

CHAPTER IV.

STRUCTURE OF ANIMALS AS COMPARED WITH THAT OF MAN.

Although it is no part of the plan of this work to enter into a detailed account of the Natural History of animals, especially of their scientific arrangement, still it will be necessary to give some general description of the system of classification usually received among naturalists, and of the principles on which it is founded.

The functions briefly described in the last chapter, by which life is maintained, are few in number and definite in purpose. They are essentially present in all animals: that is to say, it is necessary to all that their systems should be supported by blood, which is effected by a circulation of some kind, however simple; that this blood should be regularly exposed to the influence of the air by respiration; that the effete particles should be removed from the textures by absorption, and from the body by secretion and excretion, and that they should be restored to the blood by digestion. It is necessary, also, that they should have a perception of objects external to themselves by means of sensation, and the power of moving the parts of their body by the will or locomotion. These functions are present in all, though performed in a much more limited manner in some than in others; so that,—notwithstanding this essential identity of function,—in no two is there the same form and structure. They exhibit an almost endless variety in the manner in which the objects of life are accomplished, and out of this grows their almost endless variety in external form, and in some degree, though to a far less extent, in their internal organization.

This variety seems intended to adapt them to different residences, to live in different mediums, and for their universal distribution over the surface of the earth. It is thus that quadrupeds are fitted for the land, birds for the air, and fishes for the water; and it may be taken as a fundamental principle, that the varieties of external form and internal organization which animals exhibit are intended to adapt them for something in those particular external circumstances in which they are placed. The reason is obvious enough why this should be necessary with regard to their organs of sense and motion, but not so clear with regard to their internal structure. Yet it is not less so. A correspondence is found to exist between all the parts of an animal. It may be *primarily* necessary, in order to adapt an individual species to its destined residence and kind of food, that only a single set of its organs should be modified, but then, on account of the intimate relations and reciprocal dependence of the functions, it becomes *secondarily* as necessary that some modification take place in every other organ, in order to that perfect harmony of action which Nature requires.

Suppose we substitute for one of the wheels of a watch, another which has a single tooth less. By even so slight an alteration as this, the whole movement of the machine will be deranged. It will cease to keep exact time, because the correspondence between all its parts has been destroyed. This can only be remedied by remodelling every other part so as to restore this correspondence. Here, perhaps, we must substitute a smaller wheel, and there a larger; this lever must be longer, and that shorter; and so on till the movements are again equalized, and harmony restored. Similar modifications are required in the more delicate and more nicely adapted machinery of which the bodies of animals are examples. Alter the mode of performing one function, and you disturb its harmony with the others, unless at the same time you introduce a corresponding modification into them.

This would be in fact to make a new animal. It is in this way, indeed, that Nature makes new animals, or, to speak more exactly, in this way she has been able, out of a limited number of organs and functions, to produce the immense variety of kinds with which her dominions are filled.

When an animal is to be constructed to live upon food not very unlike that of man, but to seek it in a different way; in a particular part of the earth, where it is presented to him spontaneously through the whole year, and therefore requiring a less varied intelligence; obliged to ascend trees, partly to procure this food and partly to escape his natural enemies, — Nature does not invent a new plan, but makes certain necessary alterations in her old one. She takes man. She shortens and weakens his legs, but lengthens and strengthens his arms. She takes away his feet and gives him hands upon all four of his extremities, less perfect than those of his prototype, but as perfect as his purposes require. She sharpens some of his senses, but diminishes his intellect. She gives him, therefore, a larger face with a smaller head, and then, after a variety of changes in correspondence with these, she has converted a man into a monkey.

Something analogous to this we observe among mankind in a variety of their works of art. From time immemorial, man has navigated the ocean in vessels impelled by the wind, and he has constructed them accordingly. But a new agent of motion, steam, is discovered, and this he desires to apply to the propelling of vessels on the water, as well as of machinery on land. He does not cast aside his old model, but modifies it and adapts it. With the same general shape and framework, certain parts are made stronger to endure the weight and motions of the ponderous machinery; other parts weaker because they have no longer to endure the strain of the masts and sails; some parts formerly devoted to other purposes must be now devoted to the stowing of fuel. Then the construction varies according as the vessel is intended to navigate a river, a lake, or the ocean, to be used in commerce or in war. In short, a new kind of structure is developed, in which all the parts are modified according to the new purpose. With our limited faculties this is only accomplished after long experience, many mistakes, many disasters, and, after all, the work is clumsy, and the harmony of parts imperfect, when compared with those examples of the same process with which the Creator has so profusely surrounded us.

It is by the pursuance of this plan that all Nature has been made full of life. Were there only a single form of animal existence, the earth would be for the most part untenanted. Man occupies but a small part of its surface and consumes but a small part of its productions. By the multiplication of the forms of life, there is an animal for every place and a place for every animal. As a general rule, there is no waste of material; the variety of life furnishes a consumer for every product. The deer feeds upon grass, and is seized by the wolf; the wolf dies, and furnishes food for a thousand insects; these also are devoured in their turn, — whilst all those vegetable and animal products not thus directly appropriated to the support of life, in their decay indirectly subserve to a more luxuriant vegetation, and reappear in new forms to answer the same purposes.

Thus it is that a great variety of kinds among animals is a necessary provision in a world constituted as this is; the final cause being that no room should be unoccupied, but that life and enjoyment should pervade every part. It follows that there will always be found a correspondence between the manner in which the ends of life are accomplished in each species, and the sphere in which that species is intended to move. Naturalists, in their examination of the animal kingdom with reference to its history and methodical arrangement, have always reference to this correspondence, and it is expedient, in order to the clearest illustration of the subject, to state somewhat more minutely the principles on which this correspondence of structure to purpose is regulated. In order to this, we may take one of the functions most immediate to life and see how its organ, and the mode and the quantity of its performance, are modified in this way.

One of the most important circumstances of external condition is the medium in which an animal resides, air or water. It renders necessary some modifications in shape, organs of motion, senses, covering, weapons of defence, &c., but more especially it renders necessary an appropriate structure of the organs of respiration.

Animals which breathe air have *lungs*, into the interior of which air enters, and, through their *internal surface*, exercises its influence on the blood. Animals that breathe in water have *gills*, or *branchiæ*, over the outside of which the water is made to pass, and, by means of the air that it contains, influences the blood through their *external surface.*

As the quantity of air contained in water is small, the quantity of blood renovated by its influence in a given time will be small, unless the organs of respiration are made very extensive. But this is not necessary to the condition of aquatic animals, and consequently the blood is proportionately less rapidly and frequently renovated in fishes than in quadrupeds and birds.

A variety of consequences, more or less direct, follow from this difference in respiration. The organs of circulation will be modified to correspond, and so too the structure of the body in other particulars. Air may be conveniently drawn into an interior cavity of the body, but this could not be conveniently done with water in the large quantities employed, especially as it is necessary that it should pass in a continued and rapid stream over the gills. The apparatus for inhaling and exhaling air must be very different from that destined to produce the requisite current of water; consequently the form of the head and chest, and the interior arrangement of the organs contained in them, will undergo more or less modification.

There is a close relation between the exercise of muscular power and the amount of respiration. Muscular action produces very rapidly that deterioration in the blood which it is the province of respiration to repair. Hence those animals whose mode of life calls for very extensive motion, require an ample respiratory apparatus. Birds and insects are of this description. Living and moving in the air, their motions demand a much larger expenditure of power than those of animals that are confined to the surface of the earth. Accordingly in them the respiratory apparatus is more largely developed than in other classes. The air in birds is not only conveyed to the lungs, but is also distributed to every part of the body; whilst the bodies of insects, which have no distinct lungs, are in all parts pervaded by it.

In reptiles and fishes, the opposite state of things is observed; their motions are comparatively slow, sluggish, infrequent, and requiring little exercise of power. In accordance with this, their respiration is limited; in the former, by the admission of a comparatively small quantity of air, and in the latter, by the substitution of water for air, as the medium through which the function is carried on.

For the same reason that an active and extensive respiration implies a powerful muscular apparatus, it also requires a powerful digestive apparatus to supply the greater waste of material which is thus occasioned. Not that respiration simply considered requires a large supply of food, but the increased activity of other organs, especially those of motion, which attend an extensive respiration, requires such a supply. Hence in birds the digestion is more vigorous and speedy than in other animals, and they need the most frequent supplies of food, while reptiles eat but seldom and endure long fasts.

The several functions that have been mentioned are all, then, connected with respiration by certain laws of relation which do not admit of essential exceptions, and require a modification in the organs by which they are performed. It is not intended to imply that all varieties in animal structure are due to a controlling influence in the respiratory function. On the contrary, this influence is controlled and qualified by the others. We might as well assume some of the other functions as the standard, — circulation, digestion, or locomotion, — and by following out the same process of comparison, arrive at analogous results. Thus the organs of locomotion in the fish, and the power displayed in its movements, imply a mode of respiration inferior in extent to that of birds and quadrupeds, as much as their mode of respiration implies an inferiority in locomotive power. Either of them, examined first, implies the other. A corresponding remark may be made concerning birds. Their extensive provision for the supply of air, on the one hand, implies the existence of an extensive and vigorous muscular apparatus, — whilst, on the other, the fact of the existence of such an apparatus implies an abundant supply of air. Whichever condition is first known to us, we may with certainty infer the other.

But it is impossible in any way so well to illustrate the law of animal construction to which reference has been made, as by quoting the words of Cuvier, the great father of the modern science of Natural History, who has explained it, both in principle and in one of its applications, in the following luminous remarks.

"Every organized being consists of parts which correspond mutually, which concur by means of reciprocal influences to a common end, and thus form a whole, a perfect system. No one part can change without the others being modified, and, consequently, each taken separately, indicates all the others.

"Thus if the stomach of an animal is adapted to the digestion of raw flesh, the jaws must be constructed for devouring prey, the claws for seizing and tearing it, the teeth for lacerating and dividing its flesh, the whole apparatus of moving powers for pursuing and overtaking it, the organs of sense for perceiving it at a distance. Nature must, moreover, have implanted in the brain an impulse or instinct leading such a creature to conceal itself and lie in wait for its victims. Such are the general conditions of the carnivorous regimen. Every flesh-devouring animal unites them necessarily; for its species could not otherwise subsist. But beside these general conditions there are subordinate ones, relating to the size, the species, and the abode of the prey, and each of these secondary conditions gives rise to differences of detail in the forms which result from the general laws. Hence not only the class, but the order, the genus, and even the species, are expressed in the form of each part.

"To give the jaw the power of seizing, a particular form of the part which forms the joint of the bone is necessary; there must be a certain relation between the position of the resistance, the moving power, and the fulcrum; a certain volume in the temporal muscle,* requiring a proportional capacity in the cavity which lodges it, and a proportionate convexity in the zygomatic arch under which it passes; this bony arch must also possess a certain strength to support the action of the masseter.*

"In bearing away the prey, a certain force is required in the muscles that raise the head; hence the necessity of a determinate form in the vertebræ, whence these muscles arise, and in the occiput, where they are inserted.

"For dividing flesh, cutting teeth are required; and they must be more or less cutting, in proportion as they are more or less exclusively occupied in that way. Their basis must be solid, if they are employed in breaking and comminuting bones, particularly if the bones are strong. These circumstances will influence the development of all the parts employed in moving the jaw.

"Mobility of the toes and strength of the nails are necessary for seizing the prey; hence arise determinate forms of the fingers, and particular distribution of muscles and tendons. There must

* Muscles which move the jaw.

be a power of rotating the forearm, and consequently a particular form of the bones composing it; and, as the latter are articulated to the humerus (bone of the arm), any alterations in them must modify its figure.

"Animals which employ their fore limbs in seizing must have strong shoulders; the shoulder-blade and collar-bone will accordingly exhibit certain modifications. The muscles must have forms, size, and strength, suitable to the actions of which the bones and joints just enumerated are capable; while their attachments and contractions impress a particular figure on the solid organs.

"Similar conclusions may be drawn respecting the posterior extremities, which contribute to the rapidity of the general motions; respecting the composition of the trunk, and the form of the vertebræ, which influence the facility of these motions; respecting the bones of the nose, of the orbit, and the ear, which have obvious relations to the degree of perfection in the senses of smelling, seeing, and hearing. In a word, the form of the tooth determines that of the jaw, — the form of the shoulder-blade that of the nails; just as the equation of a curve indicates all its properties. As in taking each property separately for the basis of a particular equation, we might arrive not only at the ordinary equation, but at all the other properties whatever, so the nail, the scapula, the head of the jaw-bone, the thigh-bone, and all the other bones, taken separately, would each indicate the kind of teeth, or would indicate each other reciprocally; and, beginning with either separately, we might according to the rational laws of the organic economy construct (or calculate the construction of) the whole animal."

So much truth has been found in these remarks of this great philosopher, that what he has thus intimated has been repeatedly done both by himself and others; namely, from a few remaining parts of some extinct and unknown animal, the undiscovered parts have been calculated, and the anatomical character of the whole individual has been determined. So complete is this correspondence of parts, that a distinguished living naturalist, from a few scales of a fish, has decided the probable form and character of the extinct species from which they came.

But although Nature has thus been governed by strict rules in the construction of the organs of primary importance, there is some considerable latitude with regard to those that are of secondary. Thus in the dog, notwithstanding the great differences exhibited by the several varieties of this animal in color, shape, size, quantity of hair, expression of countenance, and other external characteristics, anatomists do not detect any corresponding differences of internal structure. It is not unlikely that even these varieties may be actually owing to the operation of some definite laws of Nature; but, if so, we have not yet attained to a knowledge of them.

It is upon considerations derived from the study of the animal kingdom in these relations, that systems of classification have been founded; and, although it is no part of the plan of this work to teach systematic zoölogy, yet is it necessary to have some such system before us in order to the most perspicuous treatment of our subject.

In a system of classification, animals are arranged in certain divisions, and these divisions are distinguished by characteristic marks. The divisions universally recognized as founded in Nature, are those of *genera* and *species*. Each distinct kind of animal constitutes a species, and there is usually supposed for each a distinct creation. The dog, the horse, the cat, are distinct species, and in them the essential characteristics of structure do not vary. Still there are many differences in subordinate particulars, especially with regard to external peculiarities, which give rise to what are called *varieties*. These varieties are most numerous among domesticated animals. Thus in the horse, the Canadian pony is an example of variety in size, — the race-horse and cart-horse of variety in shape and proportion, — black, bay, and white, in color. Other domestic animals, the cow, sheep, fowl, dog, exhibit varieties as great. But examine the feet, the teeth, the heart, the lungs, the stomach, the intestines, of the individuals that vary so much externally, and the difference vanishes.

When a number of species resemble each other so closely in some of the secondary peculiarities of anatomical structure as to distinguish them from all others and give them a kind of family likeness among themselves, they constitute a GENUS. Thus the genus Felis includes all those of the cat kind; and these animals, although differing one from another very much in size and color, have yet a close resemblance in their general form, figure, character, and habits of life. The genus Canis includes those of the dog kind; the wolf, the fox, the jackal, and the domestic dog, of which the same remark may be made. Thus, too, the horse, the ass, and the zebra are of the same genus, Equus, on account of their obvious general similarity.

The genus then is made up of a number of species, there being as many species as there are sorts of animals. Thus the cat, the tiger, the lion, leopard, jaguar, and catamount are all separate species; but taken together with others, they constitute the genus Felis. Thus, too, the genus Canis contains the dog, the wolf, the jackal, the fox, &c., which are all so many distinct species. The genus Sciurus contains the gray, red, striped, and many other squirrels. In treating of any particular animal, naturalists are accustomed to designate it by a name derived from its genus and species. This name is composed of two words; the first being the name of its genus; and the second, the name of the species, being altogether arbitrary, or else expressing some circumstance relating to the color, size, or residence of the animal, which serves in a degree to distinguish it from others. The first is called its *generic*, the second its *trivial* or *specific* name, and they correspond very closely to the names of human individuals; the generic term answering to the *Surname*, which designates the family to which any one belongs, and the trivial to the *Christian* name, which designates the particular individual.

To give an example: the different species of the genus Felis, above mentioned, are distinguished one from another in the following manner. The lion is called Felis leo; the tiger, Felis tigris; the leopard, Felis leopardus; the jaguar, Felis onca; the lynx, Felis lynx; the serval, Felis serval. In the genus Canis, the dog is called Canis domesticus; the wolf, Canis lupus; the black wolf, Canis lycaon; the fox, Canis vulpes. In this way, each animal is capable of being clearly and accurately designated, by a name less liable to mistake and confusion than its common one, which is sometimes applied to several different species. This is called the *scientific* or *systematic* name.

But beside this natural and obvious division into genera and species, many others have been constituted, arranging the genera into a variety of groups, according to principles of classification which have been founded more or less on anatomical considerations, and have varied from time to time with the progress of knowledge.

In the late work of Professor Agassiz upon the Zoölogy of the United States, a different view from that commonly entertained is presented, and copiously illustrated. According to him, none of the divisions of natural objects are arbitrary, but strictly founded in nature, and are parts of the plan of the creation as it existed in the mind of its Designer.

The following are the divisions according to which he would thus arrange all the subjects of the animal kingdom.

1. Branch; founded upon differences in the plan upon which animals are constructed; of which there are four, Vertebrata, Articulata, Mollusca, Radiata.

2. Class. Each Branch is divided into classes, according to the mode in which the plan is carried out. Thus the general plan of vertebrated animals is the same in all, but is carried out in different ways in Mammalia, Birds, Reptiles, and Fish.

3. Order. This is constituted according to the degrees of complication in the execution of the plan.

4. Family. By the form of animals, as far as determined by structure.

5. Genus. By the details of the execution in special parts.

6. Species. By the relations of individuals to one another, and to the world in which they live, as well as by the proportions of their parts, their ornamentation, &c.

CHAPTER V.

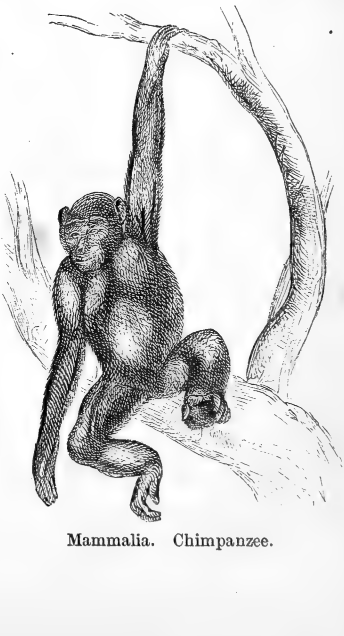
GENERAL SUBDIVISIONS OF THE ANIMAL KINGDOM.

In order to convey to the student an intelligible view of the great plan according to which the Creator has distributed animal life over the surface of our earth, it will be necessary to present such a sketch of the subdivisions of the animal kingdom as the amount of information of the general reader will enable him to comprehend.

In the first place, the whole animal kingdom is arranged under four grand divisions, branches, or sub-kingdoms, according to the PLAN upon which different animals are constructed. Thus the monkey is constructed upon one plan; the bee upon another plan; the oyster upon another; and the starfish upon another. There are, then, the following grand divisions:

1. Vertebrata.
2. Articulata.
3. Mollusca.
4. Radiata.

Fig. 6.



Mammalia. Chimpanzee.

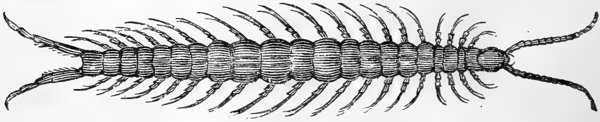
These are each, again, subdivided into classes, according to the mode in which the plan is carried out. Thus among the Vertebrata; in quadrupeds, the plan is carried out in one way; in another way in Birds; in another in Reptiles; and in another in Fishes.

Each class is again subdivided into orders, families, genera, and species, in the arrangement of which regard is had to more particular details of structure and form.

I. The Vertebrata, Vertebral animals, of which man is the representative and the most perfect specimen, are formed after his model, varied according to the conditions of existence for which they are intended. They have all a vertebral column which is the basis of an internal bony skeleton; a nervous system comprising a brain contained in a cranium and a spinal nerve inclosed in the vertebral column, from which the nerves are distributed to the whole body; five senses; four extremities, or parts corresponding to them; two jaws moving vertically; and a heart circulating red blood. Among them are terrestrial, aërial, aquatic, and amphibious animals. Some of them breathe only air; and some breathe it through the medium of water. Man, quadrupeds, birds, reptiles, fishes, are representatives of this branch.

II. The ARTICULATA, Articulated animals, so called because their bodies are composed of a succession of segments, rings, or joints, which are movable upon each other. They have no internal skeleton, but, instead, an external case or envelope, firm and solid as bone in some, soft and yielding in others. To the internal surface of this the muscles are attached, and it thus forms the basis of the motions of the animal, and takes the place of the bones of the Vertebrata. They have a head, but no proper brain. The nervous system consists of a knotted cord, differently developed in different cases. They have the senses of sight, touch, and taste; and many of them probably those of hearing and smelling, though their organs are not obvious. Some of them have no legs, but, if any, never less than six, and often many more. Their bodies are symmetrically arranged, — *i. e.* the two sides correspond to each other. Some of them are winged insects; others inhabit the water, as the leech; and others crawl in or upon the earth, as the centipede and worms.

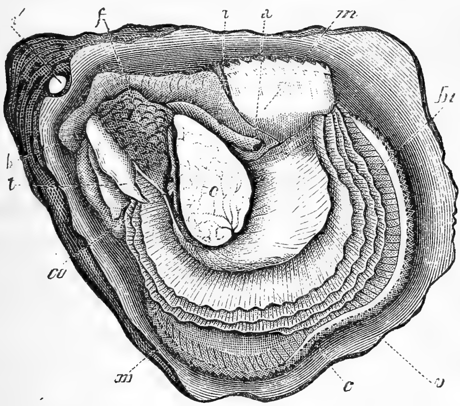
Fig. 7.



Articulata. Centipede.

III. The MOLLUSCA, soft-bodied animals, derive their name from the peculiar structure of their bodies, which are destitute of any proper bony framework, within or without. Many of them, however, as shell-fish, have an external shell as a means of defence, but it does not form the point of support to the muscular system, like the bones of Vertebrata and the external envelope of Articulata. The functions of sensation and locomotion are, with some exceptions, of a low order, whilst those of digestion, circulation, and respiration are highly developed. Cuttle-fish, squid, cockle, snail, oyster, clam, quahaug.

Fig. 8.

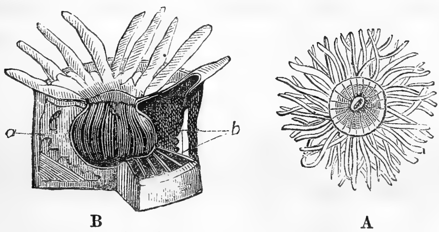


Mollusca. Oyster.

v, one of the valves of the shell; *v'*, its hinge; *mm*, lobes of the mantle, one of which is folded back; *c'*, muscles of the shell; *br*, gills; *b*, mouth; *t*, tentacula; *f*, liver; *i*, intestine; *a*, anus; *co*, heart.

IV. The RADIATA are so called from the circular arrange-

Fig. 9.



B A

Radiata. Sea-anemone.

A, represents the animal as seen from above. In the centre is the mouth surrounded by tentacula with which its food is seized and conveyed into it. B, a section exhibiting its internal organs. *a*, cavity of stomach, which is surrounded by *b*, a series of chambers, in which the germs of the young are developed.

ment of their organs around a central spot, at which the mouth is situated. The animals of this division are commonly denominated Zoöphytes. The organs of sensation, of locomotion, of circulation, of respiration, and the nervous system, are very imperfectly developed, and cannot be always detected, and in many of the lower tribes scarce any trace of organization is to be discovered. Starfish, sea-anemone, polypes, sunfish, coral animals, infusoria.

CHAPTER VI.

FIRST BRANCH.—VERTEBRATA OR VERTEBRAL ANIMALS.

These are divided into four classes: *

1. Mammalia or Mammals.
2. Birds.
3. Reptiles.
4. Fishes.

The first two classes are distinguished by having a fixed temperature above the ordinary temperature of the medium in which they live. The last two by having a temperature varying but little from that of such medium. Hence the former are called *warm-blooded*, and the latter *cold-blooded.*

Of the warm-blooded animals, those of the first class produce their young alive, and nourish them during infancy by their own milk, secreted by organs called *mammæ* or breasts. Hence their name. This includes man, quadrupeds, seals, whales. Those of the second class, or Birds, produce their young by means of eggs, hatched usually by the heat of their own bodies, and support them by food, which they provide for them as soon as they come out of the egg. These two classes resemble each other also in the general structure of the organs of respiration and circulation.

* A different disposition of the classes of Vertebral animals has been suggested, increasing their number to nine or ten, by a subdivision of those of Reptiles and Fishes. Doubtless there may be sufficient grounds for this new arrangement, but they are such as can only be intelligible to well-instructed naturalists, and it has seemed preferable, therefore, to adhere to the old and generally understood divisions.

The first of the classes of cold-blooded animals, Reptiles, contains those which breathe air only and cannot exist without it, as lizards, frogs, tortoises, serpents; the second, or Fishes, those which receive the air through the medium of water by means of branchiæ or gills.

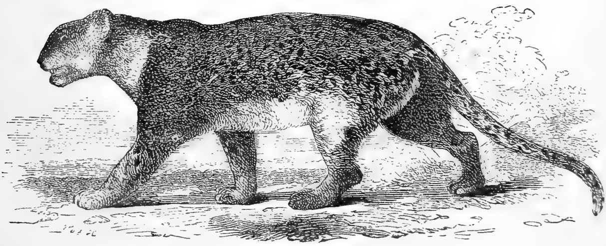
SECTION I.

CLASS I. — MAMMALIA.

Of the structure of man, the most perfect example of this class, an account has already been given, and we shall get the most intelligible idea of that of the other Mammalia by tracing the degree and manner in which they depart from him.

We have already adverted to the manner in which the structure of man is modified in the formation of the monkey tribe, p. 33, (Fig. 6.) The locomotion of these animals is chiefly that of climbing. On level ground they scramble along rapidly enough, but clumsily and imperfectly, whilst among the branches of trees they make their way with astonishing ease and rapidity. This is owing partly to the presence of hands upon all four of their extremities, but quite as much to the different distribution of force between the upper and the lower limbs. Man is comparatively a poor climber. His chief strength is in his legs. It is with difficulty that he raises his body with his arms. The monkey's greatest strength is in his arms, and the advantage which this gives him in climbing will be seen at once.

Fig. 10.



Panther.

We trace a farther departure from the human standard in the proper carnivorous animals, like the cat tribe, and in the gnawing tribe, like the squirrel. These, although differing from each other in so many particulars, are yet somewhat alike in the manner in which they differ from man. The fore limbs are brought nearer together and are directed forward; the chest is narrow, especially at its upper part; and the shoulder and arms have much less freedom and variety of motion. The fingers are not separate, but enveloped and confined by the skin; there is no thumb, and claws are substituted for nails. The wrist and heel are removed farther from the fingers, and, as a consequence, motion, which is wholly on the four extremities, is performed upon the ends of the fingers and toes instead of the hand and foot. Hence the arm and thigh are both shorter; and the elbow, or the joint corresponding to the elbow, and the knee, are carried up toward the body. The fore limbs are still, however, capable of performing some of the offices of hands, as we see in the common cat, and more especially in the squirrel. The panther and jerboa are also examples of the same structure.

Fig. 11.

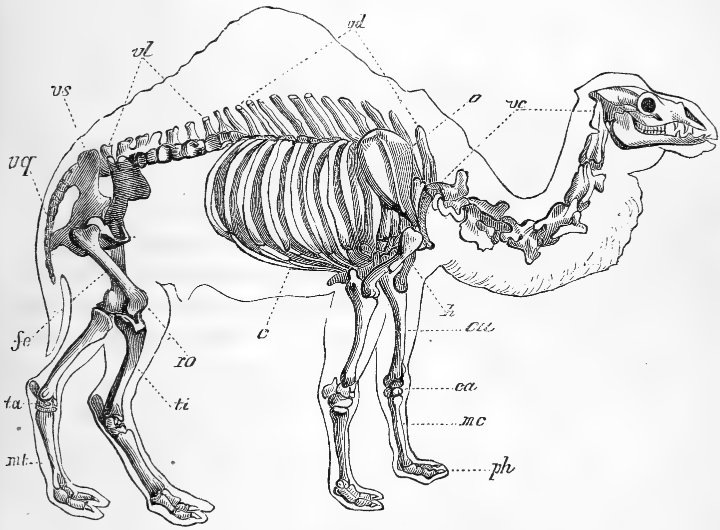
Jerboa.

Still considerable freedom of motion remains. Many of these animals use their fore paws as hands with some dexterity, and are excellent climbers, as the squirrels, though they have not the power of grasping which distinguishes the monkeys. Some of them naturally, and others by force of education, are capable of assuming the erect posture, by throwing themselves backward upon their heels and bending the knee and hip joints at very acute angles.

All the animals of these tribes are not constructed alike; for, whilst there are some not far removed from the monkeys in their structure and capacity for motion, others approach to the more complete quadrupeds.

As familiar examples of these last, namely, the complete quadrupeds, we may take the ruminating and the single hoofed animals, the camel, (fig. 12,) the ox, and the horse. In these the chest is still more contracted, — the arms or fore legs are brought more closely together, — all freedom of motion in the shoulder joint is lost; — the bones of the fingers are united into a solid mass, and form a round limb terminated by one or more hoofs. The same takes place in the hind limb. The heel is further raised from the ground, and the animal can no longer throw himself back upon it, but, as in a horse that rears, always supports himself on the ends of the toes.

Fig. 12.



Skeleton of Camel.

In this figure the single line drawn around the skeleton indicates the outline of the living animal; *vc*, the vertebræ of the neck; *vd*, of the back; *vl*, of the loins; *vs*, of the sacrum; *vq*, of the tail; *c*, the ribs; *o*, shoulder-blade or scapula; *h*, arm; *cu*, fore-arm, a single bone corresponding to the two bones between the elbow and wrist in man, — between these two bones is the joint corresponding to the elbow; *ca*, bones of the wrist; *mc*, of the hand; *ph*, of the fingers; *fe*, of the thigh; *ro*, of the knee; *ti*, of the leg, in place of two in man; *ta*, of the ankle; *mt*, toes.

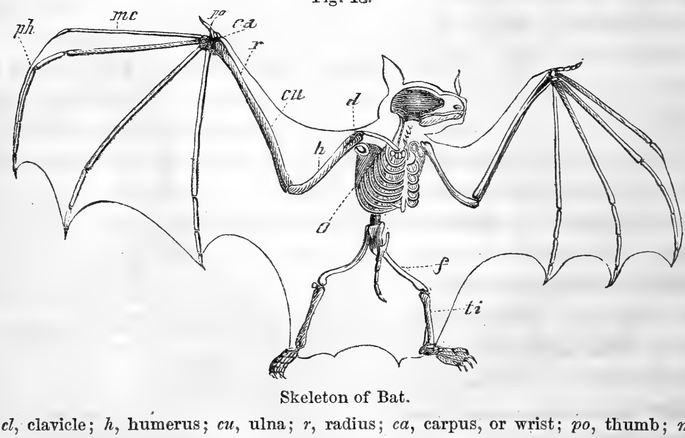
By a comparison of this skeleton with that of man (p. 23) and with the account of the gradual transition of form which takes place from the structure of man to that of the complete quadruped, a conception will be obtained of the changes there referred to.

We have noticed only the stronger distinctions of formation. In every case there are species lying between, in which a gradual transition of structure may be traced. To notice them, would lead to a too minute detail.

These variations are all connected with the kinds of motion required by the necessities of the animals in which they are found. There are others in which a greater departure, from the residence and habits of man requires a still greater departure from his structure. Some Mammalia, as the bats, are intended to move in air; — others, as the seals and whales, in water.

It would have been difficult to imagine how the same fundamental structure, which, by no essential modification of plan, has been transformed from a man to an ox, could, without greater violence to the plan, be converted into a bat. But this is exactly what has been done. Examine the skeleton of this animal, and you find it is essentially built like that of man. The parts are the same; — the proportions only are altered. It is chiefly to be observed, that all four of its limbs are put in requisition for the purpose of flying; just as in monkeys for climbing, and in quadrupeds for walking and running; the fore limbs being reserved

Fig. 13.



Skeleton of Bat.

cl, clavicle; *h*, humerus; *cu*, ulna; *r*, radius; *ca*, carpus, or wrist; *po*, thumb; *mc*, metacarpus; *ph*, fingers; *o*, scapula; *f*, thigh; *ti*, leg.

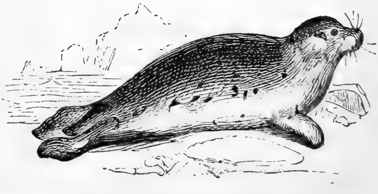
By continuing the comparison with the human skeleton, the points in which that of the bat at once differs and corresponds will be easily perceived. The most noteworthy variation is that which has been effected in the arm and hand. The bone between the elbow and hand is prolonged to a considerable, and those of the fingers to a very great extent, and are spread out like the sticks of an umbrella, so as to give support to the membrane of the wings, whilst those of the arm and shoulder are larger and stronger. If, especially, the relative development of the upper and lower extremities be contrasted with that of man, it will clearly appear how singularly these parts have been modified in order to accommodate them to the purposes of flight.

exclusively for higher purposes in man alone. It is also to be remarked, that in bats the faculty of flying is conferred upon them at a great sacrifice. It flies, in fact, at the expense of the powers of running, walking, and handling objects, in all which it is deficient. This is because raising a body and carrying it through the air requires so much more power than to carry it upon the surface of the earth that it is only by a concentration of its whole muscular force that it has been accomplished.

This might have afforded a lesson to those among our own species who have sometimes sought to invent wings by which to move through the air. These they have attached to the upper extremities. It is obvious that, as Nature has only been able to make one of the Mammalia fly by devoting nearly its whole muscular power to the object, if man is ever to accomplish this purpose it must be by an imitation of Nature in this particular. It is probable that the muscular power of man is as great in proportion to his weight as that of the bat. Could an apparatus, therefore, be contrived by which the whole muscular power of the body and limbs was brought to bear upon wings properly constructed, it is not impossible that the flight of bats might be imperfectly imitated.

There are other animals among the Mammalia that exhibit a similar structure in a less marked degree, as the flying lemur, flying squirrel of our own country, and the flying opossum of Australia, but these may be passed over, and we come to those in which the construction deviates from that of man in an opposite direction, being intended to enable them to live and move in and upon the water. They are of two kinds, — the amphibious, as the seal, the morse, the dugong, capable of moving both on land and water; and the cetaceous, as the whale, dolphin, and porpoise in the water alone. The amphibia retain the four limbs, the bones of which are constructed like those of quadrupeds, but they are short and enveloped by flesh and skin, whilst a membrane or web connects the fingers together to adapt them for

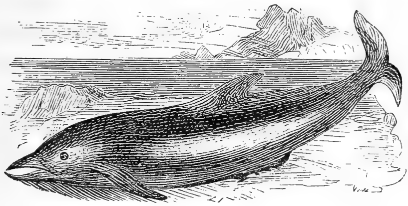
Fig. 14.



Seal.

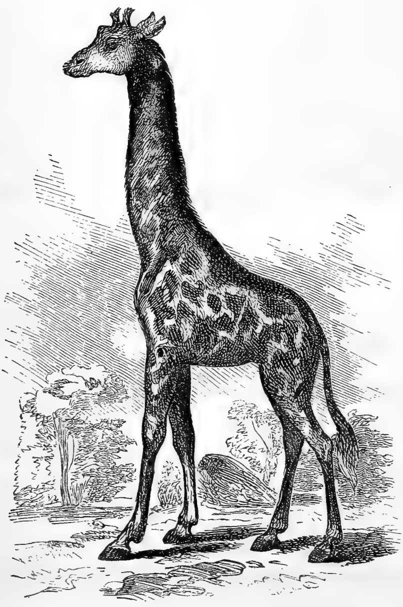
swimming. The cetaceous animals are still farther removed from man in structure, the pelvis and hind limbs being wanting and their place supplied by a form of the parts in some measure approaching that of a fish and terminated by a fin or oar, which is, however, horizontal, instead of vertical as in fishes.

Fig. 15.



Cetaceous animals are sometimes popularly confounded with true fishes. They differ, however, in essential particulars. They are warm-blooded; they are viviparous and suckle their young; they breathe air; their organs of circulation, respiration, and digestion, are like those of the other Mammalia. They are to be regarded as inhabitants of the surface of the water, rather than, like fishes, as inhabitants of its depths.

Fig. 16.



Camelopard.

Beside these general modifications of structure which characterize certain large divisions of this class, there are others more limited in their extent, but equally illustrative of the relation of structure to purpose, and of the structure of different parts to each other.

There is a striking disproportion between the anterior and posterior extremities of many animals, as compared with the average standard of the class. In the camelopard, or giraffe, the head is elevated to a height of eighteen feet, by the length of the neck, the shoulders, and the fore legs, the hind parts being only about half as high. It is thus the most lofty of quadrupeds, and is adapted to feed, as it does almost exclusively, upon the tender leaves of trees. In other animals we find a similar disproportion in the hinder parts of the body, which qualifies them for different motions and a different mode of life, — as in the jerboa and the kangaroo. In these the hind limbs are many times longer and stronger than the fore limbs, enabling them to advance by enormous leaps, whilst they can scarcely walk or run at all.

Fig. 17.

Kangaroo.

In the lion and other animals of similar habits, the neck is short and strong, with great strength in the shoulders and fore legs. These correspond to their powerful head and jaws, and qualify them for seizing and bearing away their prey. Were the neck like that of the horse, it would be impossible to furnish it with muscles strong enough to lift their large head and the prey which they have seized, at the end of so long a lever, without increasing the size to absolute monstrosity. But in the horse the head is small and light; his food requires no power to raise it, but being intended for rapid motion, and having therefore long legs, he needs a long neck to reach the herbage on which he feeds. He is not intended to use his head or mouth for the purpose of defence, but trusts for safety to a rapid flight, and repels his enemies with his heels. Compare him in these particulars with the bull, whose instruments for defence are planted on his head. His neck must necessarily be shorter and stronger. But as his food is also herbage, the fore legs are short, or he could not reach the earth. These variations all follow from the design of creation and the necessary harmony of structure. In the one case, we have an animal, fleet, with long legs, a long neck, and small head, who flies from his enemies, and, when approached, defends himself with his heels. In the other, we have another with a large head, a thick, short, sturdy neck and chest, short legs, not so well fitted for rapid motion, but well adapted for powerful resistance or attack with his head and horns.

In this way we may trace the connection of each peculiarity of formation with some use for which the parts are designed. With legs of a moderate length, the neck of the camel is long, for he is to seek his food on the ground; but it is slender because his head is small, the nature of his food not requiring a large one. With a head equally small, the neck of the giraffe is long, and raised upon shoulders of great height, because he is to seek his food above. The elephant has a very thick, short neck, on account of the immense weight of his head. His head is large because he must have great strength of bone to give support to his heavy tusks; his tusks are necessary as means of defence, and to aid him in procuring his food, which consists frequently of the branches of young trees. But with his large head, his short neck, and his long tusks, he cannot reach the ground; — he could neither eat nor drink, — he would starve in the midst of plenty but for his long trunk, which conveys water, and the food his tusks have gathered, into his mouth. Such a contrivance was absolutely demanded by the rest of his structure, and a similar necessity implies a similar provision in the mastodon, the great extinct animal of America.

Such are a few examples of the adaptation of structure to purpose, and the harmony which exists among the different parts of the same animal. Still there are a vast many peculiarities of which we cannot perceive the object; nor can we understand the design of differences among those species whose food, habits, and mode of life are apparently alike. Yet we may reasonably conclude that such differences are not without a purpose, because wherever we get at all the facts of the case we perceive such a purpose. Nor is it any objection to this view, that animals so often depart from the mode of life and the kind of food which is natural to them. There is in all a certain power of accommodation to external circumstances without permanent injury. It is no proof that the dog is not a carnivorous animal, that it can be brought to thrive on a vegetable diet; no proof that horns are useless to the ox, because there is a variety without them, any more than that our hands are useless, because some men can effect the same purposes with the mouth or the feet. In those laws of structure which relate to the essential functions of animal life, respiration, circulation, &c., such variations do not exist; in secondary provisions a great latitude and power of accommodation are observed. These secondary provisions are made, not for purposes absolutely essential, but for the comfort, convenience, or even the luxury of animal existence. To argue in any case that a provision is without an object, because it sometimes fails of that object, or because the same is sometimes accomplished without it, is a mode of reasoning forbidden by the whole analogy of Nature.

The division of the Mammalia into orders is founded upon considerations of this nature. The structure of an animal being found to correspond to its character, mode of life, and kind of food, those which have a similar structure will of course resemble each other to a certain extent in other particulars. From the formation of the extremities of an animal, particularly the anterior, we can judge of the degree of address of which he is capable, and of the kind of motions he is able to perform; and from the structure of his teeth, what is the nature of his food. Thus, the fore feet of animals may be either enveloped in hoofs, like those of the horse and the ox; armed with claws, like those of the lion; or furnished with slender nails, like those of man and the ape; and the perfection of the sense of touch will be in proportion to the delicacy of these organs respectively. Thus, too, there are three kinds of teeth: the incisory or cutting teeth; the canine or dog teeth; and the molar or grinding teeth; but all animals have not each of these kinds of teeth, nor are they in all of the same shape and formation. The molar teeth, for instance, in the carnivorous animals, are sharp and fit only for the cutting of flesh. In the herbivorous, they are broad, with surfaces adapted for grinding grain or the fibres of vegetables, which require more mastication than flesh, before they are capable of being digested.

The most intelligible arrangement of the Mammalia divides them into the following orders:

I. The *Bimana*, or *Two-handed* animals. Man is the only example of this order. He has hands upon his upper extremities alone. He has nails of a thin and delicate texture, which give to his thumb and fingers a wonderful delicacy of touch.

II. The *Quadrumana*, or *Four-handed* animals, comprising apes, monkeys, and baboons. They have hands upon all four of their extremities, but less perfect than those of man.

III. The *Carnivora*, or *Carnivorous* animals. These have no hands, but their feet are furnished with claws. This is a very extensive order, and embraces a great variety of animals.

These three orders have all the three kinds of teeth, which differ, however, in shape and strength, according to the habits and food of the different species.

IV. The *Rodentia*, or *Gnawers;* so called from the structure of their fore teeth, which are particularly adapted for gnawing. They have no canine teeth; and their claws somewhat resemble those of the *Carnivora*. This order contains rats, squirrels, rabbits, &c.

V. The *Edentata*, or *Toothless* animals; so called because they are deficient always in the incisive teeth, and sometimes have no teeth at all. Their toes are terminated by large and crooked nails, which obstruct both their sensations and motions. The sloth and armadillo are in this order.

VI. The *Ruminantia*, or *Ruminating* animals, are those which chew the cud. They are cloven-footed, and have, usually, no incisive teeth in the upper jaw. Among these are the ox, camel, llama, stag, and antelope.

VII. The *Pachydermata*, or *Thick-skinned* animals. This order includes a considerable variety of other animals with hoofs, but which do not ruminate; as the horse, the wild boar, the hog, the tapir, and the elephant.

VIII. The *Cetacea*, or animals of the *Whale* kind, distinguished by having no posterior extremities, and their anterior so constructed as to answer the purpose of fins. In this order are whales, porpoises, and dolphins.

To these may be added two other orders, which differ from the preceding in certain particulars relative to the production and care of their young; in these they approach somewhat to the characteristics of birds.

IX. The *Marsupialia*, *Marsupial* animals, distinguished by the possession in the female of a bag or pouch on the outside of the abdomen, supported by two supernumerary bones, called the marsupial bones, for the purpose of holding their young after birth. Kangaroo and opossum.

X. *Monotremata;* animals having but a single posterior outlet from the body, in which they resemble birds. This order contains but a small number of species. They are truly ovo-viviparous, that is, the young are produced from an egg which is hatched within the body of the mother, and derive no other sustenance from her before birth. Ornithorhynchus and Echidna or Porcupine Anteater.

We proceed to give some further account of these different orders of the Mammalia.

I. *Bimana.* Some writers have believed that man was originally intended to be a quadruped; and that he has learned only from long experience the mode of walking erect, and of applying his hands to the purposes for which he now employs them. They have represented him as only a more perfect kind of ape; and in support of this opinion relate stories of wild men, who have been found living like beasts in the midst of forests, destitute of speech and the arts of life; and of races of apes and monkeys who can walk erect, and imitate the manners, gestures, and mode of life of men; thus endeavoring to prove a near connection and relationship between man and these animals.

It is undoubtedly the case, that man, in his external form, resembles this order of animals much more nearly than any other; but he is yet by no means more nearly allied to them in this respect, than they are to some others, which are yet always considered as clearly distinct. The fact is, that since the animal kingdom forms a series of individuals rising, by a regular gradation, from a very humble and imperfect structure, up to a very perfect one, there will necessarily be certain points of resemblance between those which stand nearest to each other in this series. Hence the apes, which stand nearest to man, resemble him more than any other animal does, but not so much as many other animals resemble them. There is a greater difference between man and those species which are next below him, than there is between any other two species which rank next to each other in the whole animal kingdom. So that there is, in truth, no more reason for saying that man is only an improved and educated ape, than there is for saying that a bee is only an improved and educated fly, a cow an improved sheep, or a horse a perfected ass.

Man is distinguished from all other animals of the class Mammalia, by his erect attitude, and his power of walking upon two legs. This is naturally the case with no other. Some are capable of being taught to walk upon their hind legs; but they never do it with ease or from choice. The ape and monkey have, it is true, hands, very like those of the human species, which they are capable of using with great address and effect; but then they have not feet or legs which enable them to walk upright: their feet are, in fact, formed like hands, having a palm, and a distinct thumb, opposed to the four fingers, and thus are able to grasp objects. The foot of man is very different. It has nothing which does the office of a thumb, and the sole does not perform that of a palm. It is flat, inflexible, and fit only for the purpose of walking. Apes, on the contrary, are adapted for climbing; and hence the peculiarity of their structure, which enables them to grasp the small branches of trees with their feet as well as their hands. Strictly speaking, then, these tribes are principally distinguished from man by having four hands instead of two; and hence man is called a *two-handed* or *bimanous* animal; and apes, monkeys, and baboons, *four-handed* or *quadrumanous* animals. This alone would be a sufficient distinction; but there are many others founded upon a variety of considerations, derived from the general structure of man. His head is larger and his face smaller, in proportion to his size, than those of the monkey. His eyes, his ears, in short, all his senses, are adapted to the erect position. He is incapable of going upon all fours with any facility, his lower extremities being so long as to render the posture of his head painful and even dangerous.

The structure of man, and his faculties of mind, give him great advantages over other animals in point of adroitness, skill, and address. His erect position gives him the free use of his hands, which, though they have a general similarity to those of the monkey, are yet far more delicately and perfectly constructed. The thumb is larger; the fingers have distinct motions; the nails present excellent points of support, so as to admit of the handling of very small bodies; and the arms have unencumbered and various motions in every direction. Still he is inferior, in point of strength, to most animals of his size: he is slow in running, is without natural means of defence, and has almost no natural covering. So that man, who, in the social state, is the lord of the lower world, the conqueror of the rest of creation, is, by nature and when alone, the weakest, the most helpless, and the most defenceless of all animals in proportion to his size.

There are several distinct races of mankind inhabiting different portions of the earth, which differ one from another more or less in form, in features, in complexion, and in character. The causes of these varieties have never been satisfactorily pointed out. They have been attributed to climate, to situation, to manner of life; but none of these circumstances appear sufficient to produce them, and we therefore still remain in ignorance on the subject. Five distinct races are usually enumerated. 1. The Caucasian. 2. The Mongolian or Tartar. 3. The American. 4. The Negro or African. 5. The Malay.

1. The Caucasian. The individuals of this variety are distinguished by the beautiful oval form of their heads; a large and full forehead; regular and distinct features; by a face which is

small and narrow in proportion to the cranium; a white skin, varying from a light rosy tint to a deep brown; and hair and eyes of various colors. This race is called Caucasian, because its origin is referred, by tradition, to the group of mountains lying between the Black and Caspian seas, among which Caucasus has been most generally known. From thence it has spread itself over a considerable part of the known world. The inhabitants of Caucasus itself, the Georgians and Circassians, are to this day regarded as the most beautiful specimens of the human form. In the ancient world, the most celebrated nations belonged to this race. The Assyrians, the Chaldeans, the Phœnicians, the Jews, probably the Egyptians, the Persians, the Scythians, the Parthians, the Greeks, the Romans, were of Caucasian origin. In modern times, nearly all the nations that inhabit the western part of Asia, nearly all the nations of Europe, and the descendants of Europeans in America and other parts of the world, are of the same race.

They have been always distinguished for superior intellectual and moral qualities. With a few exceptions, they have maintained a decided ascendency in arms over the people of the other races, and have acquired a superiority in the elegances, refinements, and luxuries of life. They have been for ages the chief depositaries of literature, philosophy, science, and the arts, and have carried the human character to the highest degree of excellence it has ever reached.

2. The Mongolian race is principally found in the eastern parts of Asia. It is distinguished by a low stature, by projecting cheek bones; a depressed and retreating forehead; features not strongly marked; eyes narrow and oblique; a nose somewhat broad and flat; thick lips; black, straight hair; thin beard; and an olive complexion. In this division are to be arranged the inhabitants of India, of the great empires of China and Japan; the hordes of Calmucks and of Mongols; the ancient Huns; the Finnish tribes of Northern Europe, as the Laplanders; the Kamtschadales; the Esquimaux Indians inhabiting the northern parts of America; and a number of other nations and tribes of less note.

The individuals of this race are inferior in moral and intellectual qualities to those of the preceding. For the most part they have made but slight progress in civilization, the arts, literature, or science, and have remained in a semi-barbarous state. There have been, it is true, some remarkable exceptions, as in the Indian, Chinese, and Japanese Empires, where, in some particulars, great advances have been made; still all their efforts have partaken of peculiar characteristics, and have evidently proceeded from a distinct and inferior race. Occasionally they have manifested great vigor and energy in military exploits; and three times have carried the terror of their arms over the greater part of Asia, and even into Europe, under Attila, Genghis Khan, and Tamerlane. Their ascendancy has, however, generally been of short duration, as they have not the qualities suited to retain and govern the empires they conquer.

3. The African, or Negro, is remarkable for his narrow and depressed forehead; flat and broad nose; thick lips; projecting jaws; black, crisped, and curled hair or wool; black skin and eyes; and some other differences in bodily shape, which it is not necessary to enumerate. These characteristics are confined to the inhabitants of some parts of Africa, and their descendants in different parts of the world. The individuals belonging to this race have seldom been distinguished for their mental faculties or moral endowments. They have remained in a barbarous state, and are with difficulty induced to adopt the customs and habits of civilized life.

4. The American race resembles, in some respects, the Mongolian; but differs from it in having more distinct and strongly-marked features, and a skin of a copper tint. All the native inhabitants of the New World, with the exception of the Esquimaux, come into this division. In general, they have made small advances in civilization and the arts, and prefer the wandering life of hunters to the comforts of settled habitations. In the empires of Mexico and Peru, was exhibited the highest pitch of refinement to which they have ever arrived.

5. In the division called the Malay, are included nations differing very much one from another, in form, features, and character, and too imperfectly known to admit of being clearly described. Some of them, as the inhabitants of New Holland and Van

Diemen's Land, resemble the African race; whilst others, as the inhabitants of Malacca and Sumatra, and also those of the islands in the Pacific Ocean, approach sometimes the Caucasian, and sometimes the Mongolian.

This arrangement of the races of mankind is still generally received, and is that to which reference is chiefly made by writers on the Natural History of man. Recent more accurate and extended observations, however, render it probable that it may become necessary hereafter to modify and enlarge it.

An eminent American Naturalist, Mr. Pickering, as the result of ample investigations of his own, has proposed the following division into eleven races.

1. The Arabian or Caucasian.
2. The Abyssinian, inhabiting Abyssinia and a part of Nubia.
3. The Mongolian, including, beside the countries mentioned above, the greater part of the American continent.
4. The Hottentot, in the southern extremity of Africa.
5. The Malay, occupying the greater part of the islands of the Pacific Ocean, and some portions of America and of the island of Madagascar.
6. The Papuan, the Fiji Islands and a part of Papua.
7. The Negrillo, another part of Papua, Soloman Isles, and parts of Luzon, Sumatra, and the New Hebrides.
8. The Telingan, parts of India and Madagascar.
9. The Ethiopian, the northeastern portion of Africa.
10. The Australian, occupying Australia.
11. The true Negro, in the central parts of Africa.

But notwithstanding all these differences in man, he maintains everywhere a decided rank, far above that of any other animal. He is the only one that has the power of communicating thoughts and feelings by articulate speech; the only one that can properly be said to avail itself of the advantages of society; and the only one that, strictly speaking, educates its young. It is in consequence of these advantages, particularly that derived from association, that he has been enabled, under all circumstances, to acquire and preserve a dominion over other animals, either by subjecting them to his use, or at least making himself the object of their fear. It is in consequence of these advantages, also, that he has been enabled to protect himself against the severity of climate, and thus spread his species over every part of the earth. Tender and defenceless, by nature, he could only exist in the most equable and temperate climates; but, aided by the inventions and discoveries of social life, he is enabled to brave the cold of the polar circle, as well as the overpowering heat of the regions on the equator.

Man is but slightly governed by instinct. His knowledge is chiefly the result of education and experience. He knows little but what he has discovered himself, or what has been taught him by others. By means of language and writing, the discoveries and improvements of one generation are transmitted to the next, and thus are the ground of an almost indefinite progress. Other animals, being principally governed by instinct, are stationary; they neither advance nor recede in their habits or capacities; they do not improve by being associated together; and, although capable of being educated by man, they do not educate one another. The first swarm of bees that existed probably constructed as perfect a honey-comb as is made now: they do not improve upon the plan which instinct has pointed out to them; it is a plan which they did not in the first place contrive, and cannot amend. But if we compare the rude and ill-constructed habitations of savage nations with the splendid and luxurious edifices of civilized life, we instantly perceive the influence which language, society, and education have had upon the human race We are sensible of the great difference between that skill which is the result of instinct, and that which is acquired by a being capable of reasoning and speaking.

Being thus susceptible of constant progress, man is found under different circumstances in different stages of this progress. In his primitive state, he supports himself upon the flesh of animals, which he destroys in the chase, or upon fruits and roots. He has not, therefore, time to devote to the cultivation of the arts, or to the education of his children; he learns nothing but how to construct his hut, his canoe, and the implements of fishing and hunting; he clothes himself with the skins of wild beasts; and he observes the natural objects around him so far only as he can make them subservient to his purposes. When he comes into possession of the domestic animals, the cow, the horse, the sheep, &c., he finds that he can derive an easier and less precarious subsistence from their milk and flesh than from the products of the chase. He rears, therefore, numerous herds of these animals, and being only occupied in finding them pasturage and shelter, is comparatively at leisure to apply himself to some of the arts of civilized life. He manufactures clothing from their skins and wool, of various degrees of delicacy and elegance. He builds himself more commodious habitations; and from the different degrees of industry and skill, with which different individuals apply themselves to these occupations, arises an inequality of condition. Some become rich, and others comparatively poor. The rich acquire a disposition to indulge in the comforts and luxuries of life, and this is found to be inconsistent with the wandering and unsettled life which they lead as mere shepherds. Hence they are induced to fix themselves permanently upon particular tracts of country, which come to be considered as their property; and thus they gradually devote themselves to the cultivation of the soil. This enables a given portion of land to support a greater number of people, than when devoted to the feeding of herds; and, hence, as agriculture becomes established, the population of a country increases. Society also becomes settled and permanent. Every individual is able to produce more by his own labor, than is sufficient for his own support, and some therefore devote themselves to other occupations, the results of which they exchange with the laborer for his surplus. Nations also exchange with one another their superfluities. Thus commerce is established; and the arts and elegances of life are one by one brought to light, as the growing wealth of individuals and nations creates a demand for them.

II. The *Quadrumana*, as has been before observed, approach more nearly to man, both in their internal structure and external form, than any other animals. They differ, however, in the size and shape of the head, which is proportionably smaller, narrower, and less elevated; in the conformation of the face, which has a flat, depressed nose, and very prominent jaws and teeth; in the length of the arms; and in the construction of the lower extremities, which are not calculated for the erect posture, and are furnished with hands, instead of feet like those of men. Their structure fits them evidently for climbing, and their usual places of habitation are trees, on the fruits of which they feed. They maintain the erect position with difficulty; it is a constrained one, since it obliges them to straighten the joints of the hip more than is easy or natural, and to rest their weight upon the outer edges of their feet or hind hands. Generally, then, they employ all four of their limbs in walking or running; but their motions, when upon the ground, are very various and irregular.

They form a numerous tribe, and comprehend a great variety of species, known under the name of apes, monkeys, and baboons. These names are generally employed with little discrimination, but they are intended to point out some general differences of form. Thus, the apes are destitute of a tail; that of the monkeys is about the length of their bodies; and that of the baboons a very short one. Besides these, which are confined to the old continent, the sapajous, including those belonging to the new world, have all long tails; and these are, in many instances, of so much strength, as to answer in some measure the purpose of a fifth limb, enabling the animal to grasp with it the branches of trees or other objects, to assist in climbing. These are called prehensile tails. The orang-outang and chimpanzee are the most celebrated of this order, for their similarity in face and form to the human race; whilst many other species, by their elongated snout, depressed forehead, and other particulars, approach more nearly to other quadrupeds.

The Orang-outang, or wild man of the woods, which is the meaning of the name in the Malay language, is found only in some Eastern climates, and has seldom been seen in Europe; although many other animals have been exhibited under this name. He is a native of Malacca and Cochin China, but is principally found in the great island of Borneo, in the East Indies. He is from three to four feet in height; his body covered with a thick red hair; his forehead high and full; and his face of a bluish color. He is mild and docile, is easily tamed, and becomes attached to those about him. He is able, in consequence of his bodily form and organs, to imitate very accurately a great variety of human actions; but is, on the whole, hardly more remarkable for sagacity and intelligence than the dog.

The Chimpanzee (Fig. 6) is a larger animal, and has been said by some travellers to equal or exceed the size of man. This, however, is not well authenticated. His body is covered with black or brown hairs. He can be taught to walk, to sit, and to eat like men. He is a native of Congo and Guinea, lives with his fellows in troops, and by means of clubs and stones repels the attacks of man and other animals. It has been said that he constructs for himself a hut with the foliage and branches of trees; but he probably does little more than provide, in this way, a very rude shelter for himself against rain and storms.

The most remarkable of this order is the Gorilla, inhabiting the interior of Africa, and only recently well known and satisfactorily described, although imperfect accounts of him have for a long time been more or less current. He is of somewhat less than the ordinary height of man, but exceeds him much in bulk and in the strength of his limbs. He is indeed a most formidable animal, — ferocious and brutal in disposition, possessed of enormous muscular power in jaws, trunk, and limbs. Though exclusively living on vegetable food, he is disposed to attack the natives whenever he encounters them, and is more than a match for several. They hold him in great fear, and can with difficulty be persuaded to join in hunting him, even when in company with Europeans armed with rifles. He is as dangerous an enemy as the larger carnivora; still he does not stand high in amount of intelligence. His brain is small, and in these respects he is inferior to the Nschiego, inhabiting the same regions. This is a milder animal, building himself a rude habitation, and living with his mate in an imperfect domestic condition.

A few of the American monkeys, or Sapajous, are furnished with a pouch or bladder connected with the windpipe, which gives to their voice an enormous volume and a tremendous tone. They are called, from this circumstance, *Howler* monkeys.

Some of the smaller and more inoffensive species of the Quadrumana are playful, peaceable, and amusing little animals; but in general they are a noisy, chattering, mischievous race, whose distorted resemblance to the human face and figure only renders them hideous and disgusting.

III. *Carnivora.* This order includes a great number and a great variety of animals. They are furnished with the three kinds of teeth, but these differ more or less in shape from those of man and the monkeys, so as to be adapted for the mastication of animal food, upon which they subsist, either in part or altogether. They are subdivided into several tribes or families, as they are more or less carnivorous. In some of these, the molars are very sharp and cutting, and thus indicate that the animal feeds entirely upon flesh; in others, they are broader, being adapted partly for the mastication of vegetable food; and in others, they are armed with a number of points or cones, fitted for a diet consisting principally of insects. Their fore legs are capable of pretty free and extensive motions, and are furnished with nails or claws, but no thumb; whence they are inferior in manual address to the Quadrumana. They are remarkable for possessing the sense of smell to a high degree of perfection. Their organs of digestion are in general less complicated and extensive than those of other animals. The stomach is smaller, and the intestines shorter; animal food requiring less change than vegetable in order to convert it into blood.

1. The first tribe, or family, is that of the Bats. These have some points of affinity with the Quadrumana, and were arranged by Linnæus with man and the monkeys. They are sufficiently distinguished, however, by their wings. These are formed of a thin fold of skin, which extends between the two limbs of the same side, in the manner formerly described (Fig. 13.) By means of this apparatus many of them are enabled to fly with a force and rapidity equal to that of most birds; but, in others, it answers only the purpose of a parachute to break their fall from lofty places, or to enable them to perform great leaps in their passage from tree to tree. They are principally nocturnal animals, seeking their prey (which consists of insects, small quadrupeds or birds, and flesh of any kind) in the twilight, and retiring during the day to dark and hidden recesses, where they remain suspended by their claws till the return of night.

Beside the common bat, with the appearance of which all are familiar, there are many others, differing a good deal in size and disposition, inhabiting other countries. Among them is the

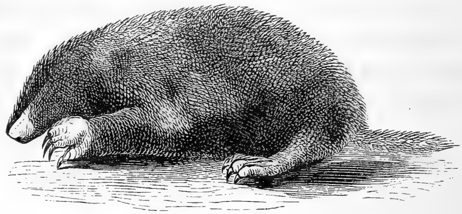
Vampire. This is from five inches to a foot in length, with a proportional extent of wing. It inhabits Africa and Asia, but is found most abundantly in the East Indian islands. It is very gregarious, and collects in immense flocks. Five hundred have been counted hanging on a single tree. It does not confine itself to animal food, but subsists also upon fruits and vegetables, and is the cause of great injury to the produce of the countries it inhabits. It has been supposed to suck the blood of persons lying asleep, by making an orifice in some exposed vein, which it does so easily as not to awaken the sleeper. It attacks in the same way cattle and horses, who are sometimes seriously injured by the loss of blood. Hence this animal has received the name Vampire, and is thought to have given origin to the ancient fable of the Harpies. It is said to be excellent food.

The Spectre Bat is a species very similar in its habits to the one just described. It is a smaller animal, not exceeding seven inches in the length of its body, and two feet in the extent of the membrane of its wings. It is an inhabitant of Australia, and exists in immense numbers. Twenty thousand have been computed to be seen within the compass of a mile. It has the same propensity for drawing blood as the Vampire, and is said to cause great injury and destruction among cattle by this means. It is of a mild disposition, and is easily tamed and domesticated.

2. The second tribe of this order includes a number of small animals, which feed principally upon insects, and are called *insectivorous.* Many of them pass the winter in a dormant state, and during summer lead a secluded, nocturnal or subterranean life. Their limbs are short, and their motions very feeble. Such are the hedgehog, the tenrec, the shrewmouse, and the mole.

The Hedgehog is remarkable for being covered with short, strong spines instead of hairs, and for the faculty of drawing its head and feet in such a manner under its belly, as to give itself the appearance of a ball covered with sharp bristles. In this way it resists the attacks made upon it, using no other method of defence; and no violence will induce it to alter its form or position. It is a harmless and inoffensive animal, and suffers injuries of all kinds with great patience and forbearance. It is about nine or ten inches in length, inhabits holes and decayed trees, into which it retreats in order to pass the winter. Its skin was used by the ancients for a clothes-brush, and has been sometimes employed for the purpose of dressing hemp.

Fig. 18.



Mole.

The Moles are peculiarly adapted, by the structure of their nose and feet, for burrowing in the earth. This operation they perform with great facility and rapidity. So expert are they, that if put upon the grass where the earth is soft, they force their way into it almost immediately ; and even upon a hard, gravelly road, they can cover themselves in the course of a few minutes. They feed principally upon the earthworm, and prefer the soil in which it is to be found in greatest abundance for their residence. They construct habitations of a peculiar form, to be hereafter described, in which they rear their young, and lead a social and domestic life. They sometimes increase in number to such an extent as to be a serious annoyance to the husbandman.

3. The animals of the third tribe possess the characteristics of this order in the highest degree. They are endowed not only with an appetite for animal food, and a structure adapted for its mastication and digestion, but with strength and courage for seizing and retaining it. They are not all, however, purely carnivorous, nor equally ferocious. Some are slow and indolent in their motions, and clumsy in their forms, passing the winter in cold climates in a state of lethargy, and being capable of subsisting in a great measure upon vegetable food. Such are the bear, glutton, and badger. There are others, as the weasel, the ermine, the ferret, and the polecat, mean in size and appearance, and of a long, lean body, with very short legs, enabling them to creep through very narrow apertures. They are small and feeble, but still extremely cruel. Others again, as the dog, the wolf, the fox, and the jackal, are possessed of a good deal of strength, but do not exhibit a proportionate degree of courage and ferocity. But the lion, tiger, panther (Fig. 10), &c., are at once the most

powerful, the most bloody, and the most ferocious of the animal kingdom. Their fore paws are endowed with great muscular power, and are armed with sharp nails, which, in a state of rest, are drawn in and concealed from sight. They are the terror of the forest, feed only upon flesh and blood, and sometimes, when driven by hunger, attack even man himself.

The Dog, so well known to all mankind, presents a great variety of shape, size, and color, according to the different breeds produced by the different situations in which he has been placed. No animal is so completely under the control of mankind. Every individual of the species gives himself up wholly to his master, obeys his voice, acquires his habits, defends his property, and, even in spite of caprice and ill usage, remains faithful till death. The dog is the only animal which has accompanied man to every part of the earth, and forms his most useful ally, particularly in the early stages of society, in bringing into subjection the inhabitants of the forest. It has been supposed by some, that the dog was originally the same with the wolf, and by others, that he is a jackal in a domestic state. But the origin of his connection with man is too remote and obscure to allow this question to be determined.

The animals of the Cat kind are all of a fierce and bloody disposition. Some are remarkable for the majesty and elegance of their form, or the beauty of their skin. The lion and the tiger are the two most celebrated species.

The Lion is a native of Asia and Africa; and is found sometimes of the length of eight or nine feet, exclusively of the tail. His appearance is majestic and dignified; and, although entirely carnivorous, he is not remarkable for cruelty or the unnecessary destruction of life, but has been sometimes known to exhibit traits of generosity and magnanimity. His muscular strength is immense; a single stroke of his paw is sufficient to destroy some of the larger animals on which he preys; a sweep of his tail will knock down a man; and he is able to carry off an ox, or even a buffalo, when lightened of its entrails, with apparent ease. In populous countries, where he is accustomed to the sight and acquainted with the power of man, he is comparatively timid, and will sometimes even fly before women or children; but in those where he is undisturbed in his dominion, he defies man as well as all other animals. The lion, when taken young, is capable of being tamed; and, in a state of confinement, has lived to the age of seventy years.

The Tiger is an inhabitant of the warmer parts of Asia and the Indian islands. He attains to nearly the size of the lion, and is of equal strength, but far more bloody and cruel. He is the scourge of the countries which he infests, and has sometimes almost depopulated whole villages. Such is his vigor and the rapidity of all his motions, that he has been known, when lurking around an army on the march, to spring from a thicket upon a soldier, tear him from his horse, and convey him into the forest without being molested. When he has seized a large animal, if uninterrupted, he plunges his head into the midst of the carcass, and sucks the blood. He is not so easily or completely tamed as the lion; but if taken young, is susceptible of a certain degree of domestication.

4. A fourth tribe of the Carnivora comprehends the amphibious animals, such as the seal (Fig. 14), the walrus, and the morse. They differ from other quadrupeds very widely in their external appearance, whilst their internal structure is very nearly the same. Their limbs are composed of a similar number of bones, arranged in the same way, yet so short and so enveloped by the skin as to be of but little use for walking. But as the intervals between the toes are filled up with skin, they form excellent oars. Hence these animals move with great rapidity and address in the water, although they can only crawl awkwardly upon land. They feed principally upon fish; and the structure of their teeth is manifestly that of carnivorous animals. They live almost entirely in the sea, and come upon shore only for the purpose of reposing in the sun and suckling their young. They breathe, however, like other Mammalia; and hence cannot constantly remain under water, but are obliged to return to the surface for air. Still they are able to live a long time without breathing; and it has been asserted that there is some peculiar conformation about their heart, which renders this possible. But no such peculiarity is found to exist.

The Seals are mild and inoffensive, except when provoked.

They are easily tamed, and become attached to those who feed them. Their head somewhat resembles that of the dog. They live together in large herds or families, and are valuable as objects of trade on account of their skins and oil.

IV. *Rodentia*, the Gnawers, are distinguished by the possession of two large incisive teeth in the centre of each jaw, and by the absence of canine teeth. There is a wide space between the incisors and the molares, which last are broad, and evidently calculated for the mastication of vegetable food. This arrangement of their teeth remarkably qualifies them for gnawing, and enables them to penetrate very solid substances; and frequently they feed upon woody fibres and the bark of roots and trees. There is an additional circumstance in the structure of their incisive teeth, which adapts them to the use for which they are intended. They are furnished with enamel only upon their front surface, so that the back part, being merely bone, is, by gnawing, worn away faster than that in front, and of course the front edge is kept sharp and fit for cutting. To remedy the loss of substance which necessarily ensues, there is a provision by which a constant growth takes place from the root; hence if one of these teeth is lost by accident, that corresponding to it in the opposite jaw, being no longer worn away by use, increases to a great length. Their feet are furnished with toes and nails, and their hind legs are stronger and longer than their fore legs; so that frequently they leap better than they run. Of this order, among others, are the beaver, the squirrel, the dormouse, the marmot, the hamster, the mouse and rat, the jerboa (Fig. 11), the various species of hare and rabbit, and the porcupine.

The Beavers have been long celebrated for the value of their skins as an article of commerce, and for the wonderful sagacity and forethought they exhibit in the construction of their dwellings. Their cutting teeth are very strong and sharp, and they are able, with them, to fell lofty trees. They are possessed of a large, long, and broad tail, almost oval in its shape, and covered with scales. It has been supposed that they employ this as a kind of trowel, to lay on the mud and clay of which their dikes are partly built. But it has also been asserted that the tail is only of use as an instrument for swimming. They are aquatic animals, and construct themselves habitations upon waters sufficiently deep never to be frozen to the bottom, preferring running streams upon which the trees they cut can float down to whatever spot they have chosen. Here they build a dam for the purpose of preserving the water always of a convenient depth, and construct their huts or cabins. Of their skill, sagacity, and intelligence, a more particular account will be given hereafter. But, although so wonderful in these respects when united in a society, they are, for the most part, helpless and timorous animals when living separately; a beaver, although pretty large and strong, and armed with powerful teeth, if he meet a man alone upon the shore, sets himself down upon his haunches, and cries like a child.

The Jerboa is a little animal of about the size of a rat, with a tail ten inches long, and limbs of very unequal size, the hind legs being six inches, whilst the fore legs are but one inch in length. It cannot of course use them all at once without great difficulty, and moves principally by leaps, which are sometimes of five or six feet in extent, or by a hopping motion on its two hind legs, which resembles that of birds. Its fore legs it employs only as hands for the purpose of holding its food. It is supposed that the ancient cony, mentioned in the Old Testament, was the jerboa, which inhabits Palestine to this day.

There is an American species, the Canadian Jerboa, which does not exceed two and a half or three inches in length. It has the same general characteristics as the animal before mentioned, and even exceeds it in the length of its leaps, which extend, if we may credit the accounts given of them, to the enormous distance of three or four yards, or nearly fifty times the length of its body.

The Hamster is an animal larger and thicker than the jerboa, and nearly allied to the common rat. It is distinguished by cheek pouches, which are capable of containing a very large quantity of food. When empty, they are so contracted as not to appear externally visible; but when filled, are stretched to an enormous extent, and are capable of containing a gill of grain. A hamster has been caught and dissected, that had stored in its pouches a quantity of beans, which, when taken out and laid in a heap, appeared to exceed the bulk of its whole body. The Canada rat is almost equally remarkable for the size of these receptacles.

Of the Alpine Marmot some account will be given hereafter. There is another species, however, which deserves a short notice. This is the Louisiana Marmot, usually known by the name of the prairie dog, from a slight resemblance of its cry to the barking of a small dog. It is a sprightly and interesting little animal, inhabiting the country around the Missouri and Arkansas rivers, and is found in villages from a few acres to several miles in extent, called by the hunters, prairie dog villages. It lives in burrows, the entrance to which is in the summit or side of a small mound of earth, somewhat elevated, but rarely to the height of eighteen inches. This mound, particularly around the entrance, is trodden down like a pathway. They delight, in pleasant weather, to sport about the entrance of their burrows, and five or six individuals may be seen sitting on a single mound. When alarmed, if the object of terror be near at hand, they retreat immediately into their holes; but if at a distance, they remain for some time barking and flourishing their tails, or sitting erect to reconnoitre.

The Porcupine is covered with hard and sharp spines, which afford it a natural protection against the attacks of other animals. In this respect it resembles the hedgehog, and, were external appearance alone regarded, would be arranged with it; but both its structure and its habits of life are different, and it is obviously intended for subsisting upon vegetable food.

V. *Edentata,* Toothless animals, so called from the absence of the incisive, and sometimes also of the canine and grinding teeth. Their toes are terminated by very large, thick, and strong claws, which approach in some degree to the nature of hoofs. The animals of this order are likewise remarkable for a great degree of torpor, listlessness, and indisposition to motion; but some more than others. The sloth, the anteater, and armadillo, are among them; and of each of these there are several species.

The Three-toed Sloth is an animal whose very aspect is painful and disgusting, from its excessive ugliness and deformity. The expression of its countenance and its whole attitude, indeed,

Fig. 19.

Sloth.

convey to the beholder the impression, that its very existence is a burden. It is about the size of a cat. Its fore legs are much larger than its hind ones, and it drags the latter after its body, as if weary of carrying them. It creeps, in fact, almost with its belly upon the ground, and does not advance more than fifty or sixty paces in a day. It climbs trees, and feeds upon their leaves and smaller branches; but such is its indolence, that, after having despoiled one tree of its foliage, it endures the pangs of hunger a long time, before it removes to another, and usually consumes a day or two in ascending or descending. Sometimes, indeed, it has been known to suffer itself to fall to the ground, rather than undergo the labor of coming down by the trunk. Such at least is the account given by some naturalists. By others, on the contrary, a different picture has been drawn, and the sloth has been represented as capable of no inconsiderable liveliness and rapidity of motion when moving over the branches of trees, which are its proper habitation, and for living among which its structure is particularly adapted.

The Armadillos are principally remarkable for their crustaceous shell or covering, which invests them like a suit of armor. This coat of mail is composed of several pieces, and marked by bands, the number of which serves to distinguish the different species from each other.

The Anteaters are totally destitute of teeth, but are furnished with a long, slender tongue. This they thrust into the habitations of ants and termites, and draw it back covered with these animals, which adhere to it by the thick, viscid saliva, with which it is covered.

The animals of this order are principally found in the warm parts of the American continent.

VI. *Ruminantia.* These are among the most distinct and well marked of the Mammalia. They have generally eight incisive teeth in the lower jaw; but, except the camel, they have none in the upper; their place being occupied by a firm callous projection. They are commonly also destitute of the canine teeth. The grinders are exclusively adapted for the mastication of vegetable food. They have neither toes nor nails, but, instead of them, their feet are terminated by a double hoof, which has the appearance of a single one cut in two. Hence they are called cloven-footed. Their fore feet, being thus deprived of the instruments of feeling, are only capable of being used, like the hind ones, for walking; and consequently they are not possessed of that freedom of motion in the shoulder-joint, which is observed in the animals previously described. Examples of this order are found in the camel (Fig. 12), llama, antelope, musk, deer, ox, sheep, and goat.

The most distinguished attribute of the ruminating animals, and that which gives to them their name, is the power of bringing their food up into their mouths, after it has been once swallowed, for the purpose of masticating it a second time. This power depends upon the structure of their stomachs, of which there are four. Of these the first three are so situated that the aliments may be made to enter either of them at pleasure, as the œsophagus terminates at a point where they all communicate together.

These animals usually feed upon grass and herbage; which substances, after being slightly chewed, are carried into the first stomach, called the *paunch;* there they undergo but little change, and are gradually transferred to the second stomach, a small globular cavity, called the *bonnet*, or *king's hood*, whose internal membrane is arranged in cells of an appearance like those of honey-comb. Having received the food, this stomach divides it into little rolls or pellets, which are successively carried up into the mouth, where they undergo a thorough mastication, and are then again swallowed and deposited in the third stomach. This, called *manyplies*, *tripe*, or *feck*, is distinguished by the numerous longitudinal folds of its internal membrane. It effects some further change upon the alimentary mass. In the fourth stomach, however, into which it next passes, the principal work of digestion goes on. This answers to the single stomach of other animals; into it the gastric juice is poured, and here the function is finally completed. During the rumination, the animal remains in a state of repose, almost of sleep; and this operation continues until the whole of the food previously swallowed has been subjected to it.

The ruminating animals have been more valuable to man than any others. They are mild, docile, and easily domesticated. Their flesh furnishes us with a large proportion of our animal food; indeed there are few other quadrupeds that man is in the habit of eating. Several of them, as the camel, the llama, ox, and reindeer, are used as beasts of draught and burden. They require, comparatively, little care, attention, or protection, and are generally contented with the cheapest and coarsest food. The milk, fat, hair, wool, skins, horns, and feet of one species or another, are made use of, for nourishment, for clothing, or for various manufactures.

The Camel and Dromedary are singularly valuable in the countries where they are reared. Without them, in fact, the great deserts of Arabia and of Africa would be totally impassable. Their structure is every way adapted for the life they lead. Their feet are very large, and divided, on their upper part, into two lobes, having each a hoof; but underneath are covered with an extremely strong, tough, and pliable skin, which unites the two together, and, by yielding in all directions, enables these animals to travel with peculiar ease and security over dry, stony, and sandy regions. They are capable also of passing several days without a supply of water: this power is probably owing to a number of large and extensive cells in the paunch, which they fill with water, and retain it for a considerable length of time, forcing it up into the mouth whenever occasion requires. It has been supposed that the camel had a fifth stomach for this purpose, but it was probably this enlargement of the paunch, which gave rise to the opinion. The Arabian camel, of which the dromedary is a variety, has one large bunch of fat upon his back, while the Bactrian camel has two. The dromedary is active and swift, and better adapted for rapid journeys; the camel more slow and deliberate, and calculated for the transportation of baggage and merchandise. The camel has lately been introduced upon this continent by the Government of the United States, and promises to form a useful addition to the stock of domestic animals.

The Llama has been called the camel of the new world. It resembles the camel in many particulars, but is much smaller, being of about the size of the stag. It is also called the Guanaco, and was the only laboring domestic animal possessed by the aboriginal inhabitants of America.

The American Bison, or Buffalo, as it is usually called, is very similar to the domestic ox. It inhabits the pastures and plains of the western parts of the United States in almost incredible numbers. In those parts of the country which they frequent, travellers report that their paths leading to and from springs and pools of water, are as common, and as well beaten, as the roads of a populous district. They are gradually retiring before the settlements of the civilized inhabitants, and will probably in time become nearly exterminated.

The Camelopard, or Giraffe, (Fig. 16,) is the most lofty of quadrupeds. It is remarkable for the great length of its fore legs, shoulders, and neck, which raise its head to an elevation of seventeen or eighteen feet, whilst, at its hips, it does not exceed half that height. Its color is white, spotted with brown. It is a mild, gentle, and somewhat timid animal, very fleet and graceful in its motions. It feeds principally upon the foliage of trees, and inhabits only the centre of Africa.

All the ruminating order, except the camel, llama, and the musks, have horns. In animals of the deer kind, they are, with some exceptions, confined to the males. They are of a hard, solid, bony substance, generally large and branching, and are periodically cast off and renewed. In the sheep, the goat, the ox, and the antelope, they are permanent, are hollow, and increase yearly in size; whilst in the camelopard they are short, conical, and always covered by the skin of the forehead, which extends over them, and by a quantity of thick bristly hairs.

VII. *Pachydermata.* This order embraces all the hoofed animals which do not ruminate. They present a greater variety than the ruminating animals, and are called Pachydermata because many of them are possessed of a thick and tough skin. They have generally incisive teeth in both jaws, and often canine teeth or tusks of very great size. Of this order are the elephant, the hippopotamus, the tapir, the hog, the horse, the ass.

The Elephant has, properly speaking, five hoofs on each foot, but they are so much enveloped by thick and callous skin as to be scarcely observable. It is destitute of incisive teeth in either jaw; and, in place of the canine teeth in the upper, is furnished with two large tusks, which sometimes attain to an enormous size. These, which furnish the ivory of commerce, are used by the animal for tearing off the branches of trees, upon which it feeds, and sometimes as instruments of attack and defence. That by which the elephant is most remarkably characterized is its trunk. This is unique among animals. It is a long and flexible organ, composed of an almost infinite number of little muscles, which contract and extend it at the animal's pleasure, and move it in every possible direction. It is in fact a prolongation of the nostrils and is endowed with the senses of smelling and feeling to a great degree of perfection. There is at its extremity a cavity of a cup-like form, into which open two canals that run through its whole length, and serve for the transmission of air and for drawing up water. At the upper edge of this cavity is a small fleshy appendage, somewhat resembling a finger in shape, which, by being opposed to the surface of the cup as the fingers are opposed to the palm of the hand, enables the animal to make use of its trunk as an organ of touch. It is nearly equal in this respect to the hand of the apes. From its length and flexibility, the trunk is capable of being bent double, and its extremity inserted within the jaws, which are below, at its base. In this way the animal's food, being taken up by the trunk, is conveyed into the mouth; whilst liquids, being first sucked up into its cavities, is injected with considerable force through its apertures into the throat.

There are two species of elephant; the Indian or Asiatic, which inhabits the southern parts of Asia and the Indian isles; and the African, found in Africa, from the river Senegal to the Cape of Good Hope.

The great Mastodon, or Mammoth, as it has been more frequently called, an animal whose bones only have been discovered, the species itself having become extinct, resembled the elephant in many respects. It has been ascertained, from its remains, that it possessed a trunk, tusks, and feet, similar to those of the elephant, and was of an equal height, but still more heavy and unwieldy. Its remains have been discovered in great abundance in North America, but rarely in any other part of the world. The bones of a smaller species have been found on the eastern continent.

The Hippopotamus, or River Horse, inhabits principally the rivers of the south of Africa, but was formerly known upon the southern extremities of the Nile. It is sometimes found ten or twelve feet in length, and six or seven in height. It has two very large tusks in the under jaw, which are partly concealed by its projecting snout and lips. These tusks were formerly used by dentists in the manufacture of artificial teeth. It is a heavy, stupid, and ferocious animal; its body is thick, massy, and clumsy; and its legs are so short that its belly almost drags upon the ground. It subsists upon roots and other vegetable substances, and frequently commits great devastation in fields of millet, corn, rice, and sugar-cane. It walks with great ease at the bottom of the water, though obliged occasionally to rise to the surface for breath. An attack upon it while in the water is dangerous, since, when wounded, it becomes exceedingly furious, and often tears to pieces the boat of its aggressors.

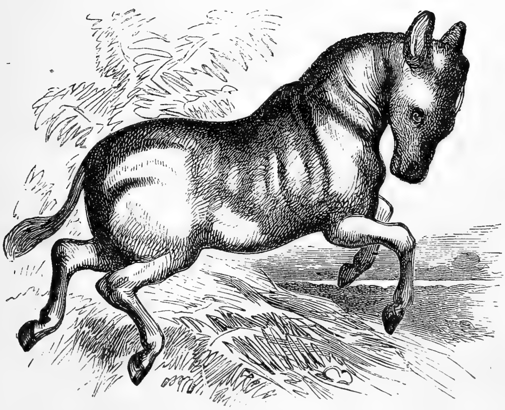
Of the Rhinoceros there are several species. The one-horned rhinoceros is somewhat larger than the hippopotamus, and is equally ferocious. It has one large and solid horn, three feet in length, projecting from its snout. It frequents moist and marshy grounds, and feeds upon herbs, roots, and branches of trees. The other species have two horns, and are generally similar in form and habits of life.

The Tapir is the largest quadruped of South America, of about the size of an ass, and inhabits marshes and low grounds. Its nose terminates in a short and movable trunk, which bears a distant resemblance to that of the elephant. It subsists entirely upon vegetables, and is of a gentle and timid disposition.

From the Wild Boar is derived the domestic Hog and all its varieties. The wild animal is violent and ferocious, and is armed with much larger and stronger tusks than the domestic. All the numerous varieties of form, size, and color, which are observed among hogs, are to be attributed to the circumstances to which they are exposed in their domestic state.

Under this order are included the Solipeda or *single-hoofed* animals, in which the whole foot is enveloped in a single hoof. Of these, the most celebrated is the horse, the most beautiful and noble of quadrupeds. These animals are distinguished, beside the formation of their hoofs, by the possession of six incisive teeth in each jaw; and, in the male, of two small canine teeth in the upper, and sometimes in the under jaw, which are wanting in the female. Between these and the double teeth, or grinders, there is a vacant space, just corresponding to the angle of the lips, where in the horse the bit of the bridle is placed, by which man is enabled to guide and restrain him. Beside the horse, which is the most valuable and highly prized of all the domestic animals, this family embraces the ass, the zebra, the dziggetai, a species between the horse and the ass in size, of a light bay color, inhabiting the central deserts of Asia, and the quagga, an inhabitant of Africa, resembling in shape the horse, but in stripes of dark and white colors, the zebra.

Fig. 20.



Quagga.

All these animals are found naturally in the wild state, except the horse. They are gregarious, live in immense herds, and subsist entirely upon vegetable food. Even the horse, in Tartary and America, is found, free from the dominion of man, collected into troops or companies, each of which is led and defended by an aged male. But in such cases it has been proved that the wild animals are the descendants of individuals that have been set at liberty by their masters, or that have escaped from them. Different breeds of horses differ, as is well known, in their color, size, speed, shape, strength, and many other qualities, which render them more or less valuable. These differences depend very much upon the care which is taken in rearing the young. The most beautiful, if suffered to become wild, will begin soon to deteriorate, and give birth to a progeny destitute of elegance and symmetry. The horse in the wild state has a large and clumsy head, rough and frizzled hair, and an awkward and disagreeable form; so different indeed is he from the domestic animal, that we can hardly recognize him as being of the same species with the noble and graceful creature that we are accustomed to behold.

VIII. *Cetacea.* The whales are sometimes confounded with the class of Fishes, which they resemble in many particulars of external appearance, as well as in the circumstance of residing always in the water. In point of structure, however, they clearly belong to the class Mammalia, since they breathe air by means of lungs, are warm-blooded, produce their young alive, and nourish them with their own milk. Instead of fore feet, they are furnished with fins or oars, which, however, are supported by bones similar to those of the fore feet of quadrupeds. They have no hind feet, but their body terminates in a thick tail, which supports a fin or oar. This fin is horizontal, whilst that of fishes is vertical.

A few of the Cetacea are herbivorous, and are frequently obliged to leave the water and crawl upon the shore in search of food. Such are the manati, usually called the sea-ox and sea-cow. They have upon their fins the rudiments of claws, which are of service to them in their motions upon the land, and with which they are even able to carry their young. The mammæ, from which they nurse their young, are upon the chest, like those of the human species; and they have, around the face, a growth of hair which resembles, in a slight degree, that of man. Hence the appearance they present when the upper part of their bodies is elevated above the water, bears some resemblance to that of mankind, and they have, consequently, been called sea-apes. It is probable that these animals being seen by the credulous, the ignorant, the timid, or the superstitious, gave rise to the ancient fables of the tritons and sirens, and, in modern times, to the various unfounded stories of mermen and mermaids.

The remainder of the cetaceous animals, such as the whale, porpoise, grampus, narwhal, and dolphin (Fig. 15), are distinguished by a peculiar construction, which has acquired for them the common name of *blowers*, and which is rendered necessary by their mode of taking their prey. In taking into their very large mouths a great number of fishes, mollusca, medusæ, &c., at once, they would swallow at the same time large quantities of water, were there not some provision for getting rid of it. To effect this, the water is passed up through the roof of the mouth, into a cavity situated near the external orifice of the nostrils, from whence it is ejected, with considerable force, through a small aperture, called the blowhole, on the upper part of the head. In some of the whales, as in the great balæna, beside this arrangement, the mouth is furnished with rows of whalebone on each side, extended in the form of thin plates, and terminating at their edges in fibres or fringes, which serve the purpose of a sieve, or strainer, to retain the large shoals of little animals that are taken in with the water, whilst the water passes through and escapes.

The Balæna mysticetus, or great Greenland Whale, is an enormous animal, which attains to a length varying from sixty to seventy or eighty feet, and is of nearly as many in circumference. Its jaws are capable of being stretched twenty feet apart, and its plates of whalebone are sometimes twelve feet in length. It is covered, under the cuticle, by a layer of a peculiar texture composed of fat and skin, called blubber, often several feet thick, and yielding according to the different sizes of the animal, from twelve to twenty tons of oil. It used formerly to frequent the Atlantic coasts of Europe and America; but to such an extent has the pursuit of it been carried, that it has gradually been driven into the recesses of remote seas.

There are other whales equal in length to this, but less valuable on account of their smaller circumference, their comparative leanness, and the difficulty of taking them.

The Spermaceti Whales are without the whalebone, and are remarkable for the disproportionate size of their heads. This size is owing to the existence of certain cartilaginous cavities upon their upper part, in which is contained the peculiar substance known by the name of spermaceti. These cavities are entirely distinct from that containing the brain, which is very small. They have little fat in other parts of their bodies; and it is on account of the spermaceti only that they are a valuable object of fishery. The odorous substance called ambergris, appears to be a concretion formed in the intestines of these whales, particularly when they are the subjects of disease.

IX. *Marsupialia.* The Marsupial and Monotrematous animals were originally distributed among those orders of the class Mammalia, to which they bear, in some particulars, the closest resemblance. Thus the kangaroo has been enumerated among the Rodentia, because it resembles them in its teeth, and the length and strength of its hind legs. The opossum has been ranked among the Carnivora, and the ornithorhynchus among the Edentata, for a similar reason. But so peculiar and remarkable is their structure, and so singular their mode of nourishing their young, that it has been found necessary to separate them into distinct orders.

The most remarkable circumstance, with regard to the Marsupial animals, is the premature birth of their young, and the exceedingly unformed and imperfect state in which they are brought into the world. They are incapable of motion, and scarcely exhibit even the rudiments of limbs or other external organs. The mouth is simply a round orifice, without distinction of parts; but by means of it, they attach themselves to the nipples of the mother, and there remain immovably fixed, deriving their nourishment from them, and gradually improving in shape and increasing in size, until they are as completely formed as other animals are at the time of their birth. So small in proportion are the young when first born, that the kangaroo, which, when full grown, is as large as a sheep, and weighs one hundred and fifty pounds, is at its birth no more than an inch in length, and weighs only twenty-one grains.

Generally, the female is furnished with a duplicature of the skin of the abdomen, which forms a kind of bag, covering the nipples, in which it places its young, and preserves them during the period of helplessness. Frequently, indeed, even after they have acquired strength to leave this pouch, they retreat into it upon the approach of danger. Sometimes, in place of the pouch, there is simply a fold of the skin. The pouch is supported by means of two bones attached to those of the pelvis, from which proceed muscles that open or contract its mouth, like the opening of a purse. These bones are found also in the male and in those species which have not the complete pouch. They are always an indication that the animal belongs to this order.

The Opossum is as large as a cat, and covered with a thick fur of a dingy cast. It hunts after birds and their eggs, and is destructive to poultry. It is found in many parts of the United States. When pursued and overtaken, it feigns itself dead, and will give no signs of life during the presence of its assailant, although tortured to a great degree. Its young, which are sometimes six or seven in number, are exceedingly minute; and, although blind and without limbs, find their way, by a sort of instinct, to the nipples, and adhere to them till they have attained the size of a mouse, which is not until the fiftieth day, when also they first open their eyes. They continue to return into the pouch, until they reach the size of a rat.

The Phalangers are found in the Moluccas and in Australia. Their tails are long, covered with scales, and prehensile. They live upon trees, and subsist upon insects and fruit. When any one approaches them, they suspend themselves by the tail, until they fall, through mere fatigue, to the ground. The Phalanger volans, or Great Flying Opossum, is about the size of a common cat, and resembles, in many respects, the flying squirrel. Like that animal, it is provided with the power of extending the loose skin of its sides when it stretches out its legs, so as in some measure to buoy itself in the air, whilst leaping from one tree to another. It can leap in this way to the distance of a hundred yards.

The Merian Opossum is remarkable for its method of carrying its young on its back, where they fix themselves by twisting their tails closely about that of their parent, clinging with their claws to its fur.

The Kangaroo (Fig. 17) is the largest animal of this order, and the largest quadruped which has been discovered in Australia. It is sometimes six feet in height, and is distinguished by the great disproportion in length between its fore and hind legs; the former being only one foot and a half long, but the latter three feet and a half. In consequence of this, they cannot walk upon all fours without difficulty, but leap with great power and to a prodigious distance, sometimes twenty feet, and to the height of nine feet. They sit upon their hind legs whilst at rest, seldom using the fore legs, except for supporting themselves when stooping to drink, for conveying food to the mouth, and for digging in the earth. But although disproportionately long, as has just been observed, when full grown, the hind legs of the kangaroo at birth are not so large or so strong as the fore legs, which are more necessary, in order to favor the motions of the little animal while in the pouch.

X. *Monotremata.* Of these the most remarkable is the Ornithorhynchus, or as it was at first called, the Duck-billed Opossum. Naturalists were at first startled, when this animal was made known to them, by the strange combination which it exhibits of the characteristics of the quadruped and the bird. It has a bill like a duck, a fourchette or wishing-bone, and spurs upon its hind feet; the limbs of an aquatic quadruped, the body of the otter, and the fur of the mole. Its young are produced in a very imperfect and unformed state, like those of the Marsupial animals; and though it has no pouch, it has the marsupial bones.

The Echidna, or Porcupine Anteater, is another animal of this order, resembling it in certain characteristic traits, but widely differing in many others, and in habits and modes of life. It is covered with spines like the porcupine; its mouth and jaws are constructed like those of the anteaters; but its relation to its young is like that of the ornithorhynchus, and it has, like this

Fig. 21.

Ornithorhynchus.

animal, spurs upon its hind feet. Like this animal, also, it is only found in Australia and some of the islands of that part of the world. With a few exceptions, this is, also, true of the Marsupialia.

SECTION II.

CLASS II. — BIRDS.

Birds are more uniform in their structure than animals of any other class. The reason of this uniformity may be probably attributed to the peculiar character of the motions for which they are chiefly intended. The muscular structure, even of quadrupeds, intended to move only on the surface of the earth, is largely devoted to progressive motion, though they are still capable of many other uses of their limbs. But in Birds, the element in which their principal movements are performed, renders it necessary that a vastly greater proportion of muscular power should be devoted to this function, and, of course, a less proportion to all others. When we consider how powerful an effort is required for us to leap but a few feet from the earth, we can easily understand how great must be that by which a bird conveys itself with ease and rapidity through the air.

So prominent are the provisions for this species of locomotion in Birds, that it is found, on examination, that their whole structure is modified in order to adapt them to this, as if it were the principal object. Not that a particular kind of locomotion actually is, in birds, or in any other animal, the principal object of existence; it always is, and must be, subordinate to other purposes. But in an animal whose kind of motion requires, comparatively, such enormous power as flying, those other purposes which are more important as it respects the nourishment, growth, exercise of the senses, and animal enjoyment, are modified in their mode of performance, so as not to interfere with this. Cut off a bird's wings, and all these great ends of life may be answered just as well as if he could still fly; and yet, such is the predominating influence which the preparation for this function has had upon his structure, that all the remaining organs exhibit indications of this influence, as much as those which have been removed.

Hence it is, that the structure of Birds as a class, connected with their peculiar mode of locomotion, affords some of our most striking examples of the adaptation of structure to purpose, and of a designing mind in creation.

Let us look at the modifications of their structure, and the purposes they are intended to answer. Their respiratory apparatus is much more extensive, and they consume a much greater amount of air than other animals. This is rendered necessary by the great amount of muscular power which is expended in flying. Where there is great muscular action, there is required a corresponding quantity of blood to support that action. This renders necessary a greater exposure of the blood to the influence of air in the lungs. Lavoisier tells us that two sparrows consumed as much oxygen from a portion of air as a guinea pig, an animal many times as large. The air, in Birds, not only penetrates the lungs, but into cells among the viscera, among the muscles, and in the cavities of the bones. This not only makes respiration more extensive, but renders the body lighter in proportion to its bulk and strength. In those birds which fly highest and longest, this provision is most ample, and is found chiefly in and about the wings; whilst in those which fly badly, like the domestic fowl, or do not fly at all, like the ostrich, it is less extensive, and is transferred from the wings to the legs. Through all these cavities the air circulates as it does through the lungs.

There is a further purpose answered by the hollowness of the bones, beside that of increasing the respiratory surface. It is an object in the bird to combine strength with lightness, and the strongest form into which any given quantity of material can be put is that of a hollow cylinder. For this reason the bones of birds are hollow cylinders. Had they been made on precisely the same plan with those of the Mammalia, it would have been necessary, in order to give them the requisite strength, that they should have been much heavier.

In the construction of the skeleton the same predominating purpose is manifest. The general plan is the same as in Mammalia, but in every part are found modifications intended to adapt the animal for flight. The backbone in the Mammalia is composed of separate pieces, movable upon each other, constituting a flexible column. In Birds, these pieces are all consolidated, to give a firm steady base to support the violent actions of the wings. The breastbone, instead of being small and narrow, is large, broad, and flat, with a projecting ridge or keel in the middle, the whole presenting a very extensive surface for the insertion and reception of the large muscles which move the wings.

Fig. 22.

Skeleton of Falcon.

In the act of flying, a very nice adjustment of the mechanical relations of different parts is necessary. The body is to be very accurately balanced upon the points of insertion of the two wings, as upon pivots, whilst in order to preserve the vertical position, the whole apparatus requires to be ballasted, as much as a ship in the water, or it would be constantly liable to misplacement, in the course of the various and sudden changes of position to which the animal is liable. This is effected by placing the point of suspension above the greatest portion of the weight of the body, especially of the large breastbone with its projecting keel and large mass of muscular flesh. The equilibrium of the body is otherwise preserved by the head and neck before, and the feet and legs behind. These usually correspond in weight, but where they do not, or when, during the act of flying, the balance is destroyed, such is the freedom of motion of these parts, that by a change in their direction, it may be thrown forward or backward. An example of this effort at maintaining the equilibrium, is seen in birds with very long necks and long legs, who in flying throw the former very far forward and the latter backward.

The anterior limbs being used for flying are good for nothing else; consequently the bird is a biped. Still it is not, like man, intended for the erect posture, but for one somewhat horizontal; and consequently the toes are made very long, and project like radii, in order to form a large base to support the body. In man, the length of the foot is about twelve inches, and its average breadth not over three and one half inches, giving an area of forty-two square inches, as a base to support the body, whose height is nearly six feet. In the common domestic fowl the extent of surface is about ten square inches, while the height of the body is from twelve to eighteen. In this way, it is enabled with two limbs to maintain a posture nearly horizontal.*

Birds, then, though bipeds, are bipeds of a very different kind from man. Man is intended for an erect, birds for a horizontal, or rather, perhaps, an oblique, posture. Hence arise certain of their modifications of structure. It is necessary that the centre of gravity should be underneath the shoulders, in order to flying, and as far back as and between the feet, in order to walking and standing. Hence, as the joints of the hip-bones are very far back on the trunk, the feet are, by the bending of the joints, thrown very far forward in order to maintain the balance of the body. This is necessary even when the head is erect, but when the head is thrown forward and downward so as to reach the ground, the

* In a male bird measured for this purpose, whose height was found to be nearly a foot and a half, the area covered by the foot was nearly ten square inches and its length from before backward no less than five inches. So that, while the height of the bird is but one fourth that of man, the length of its foot is nearly one half, in that direction in which a greater support is required.

hips are carried still farther backward, in order to equalize the weight which is thus thrown in the other direction.

Birds cannot lie down like quadrupeds, but are obliged to sleep in the horizontal posture, and on their feet. Now when awake, this requires a very nice adjustment of muscular action ; how, then, is it to be effected when muscular action is suspended by sleep? The very act of settling down upon the roost, draws up the toes in such a manner as to cause them to grasp firmly the substance they inclose. This is not due to a voluntary muscular contraction, but to a cause purely mechanical, independent of the will, and which continues till the bird awakes and arises from the perch.

The bird, thus, has no fore limbs to aid it in procuring food. Their exclusive formation for another function incapacitates them for this. The deficiency is supplied by the structure of the head, bill, and neck. The neck is long to reach the ground, but the head is light and small, or, at the end of a long neck, it would be unmanageable, and destroy the equilibrium necessary for flight. Consequently, there are no heavy, bony jaws and teeth for chewing, but food is broken up by the bill, which is strong though light, and swallowed without farther preparation. The grinding of the food and mixing it with saliva, which in the Mammalia are accomplished in the mouth, are in Birds transferred to the crop and gizzard, organs situated in the trunk of the body, near the centre of gravity. This was necessary in order to adapt them to flight. Had a turkey been made to grind up the grain it devours, like a horse, it would have required a head nearly as large as that of a cat: a size quite inconsistent with the requisite equilibrium. We trace everywhere the same subserviency of plan to the great object of constructing an animal for flight. There is a strict economy of power in every other function, in order to reserve it for this. Compare the body of a bird with that of a quadruped. Its backbone being immovable, it requires no muscles, and accordingly it is barely covered with skin ; whilst in quadrupeds, where it is supple and movable, it is furnished with a thick layer of flesh. Next the hips and legs,—except in birds which run, but fly little or not at all, as the ostrich,—are comparatively slender and deficient in power. In most quadrupeds, on the contrary, the hind limbs are furnished with many and powerful muscles, those being the chief instruments in walking and running. So, too, about the neck and shoulders there is the same economy of muscular force. This is true of the whole body till we come to the wings, where we find an immense development in the opposite direction. The breast of the bird, consisting of the muscles that move the wings, is very large, whilst that of the quadruped is comparatively small.

It will be perceived by this statement, that, though there are many provisions for maintaining a position on two feet in the bird, these provisions are chiefly mechanical in their character, — such as the large base supplied by their extended toes, and their involuntary contraction on the roost, — and do not require a large expenditure of muscular power. It is different in man, where the erect posture is maintained chiefly by voluntary effort, and hardly at all by mechanical advantage. The object in constructing the bird was to save power everywhere else in order to reserve it for the wings; except for this it might have been enabled to stand on as small a base as man. This difference illustrates very strongly the purpose of bringing about the same end by very different means according to the place the animal is to fill in creation. The same bodily posture, which in man is accomplished by a great outlay of muscular strength, is in the bird accomplished by very little; and yet for its purpose accomplished equally well.

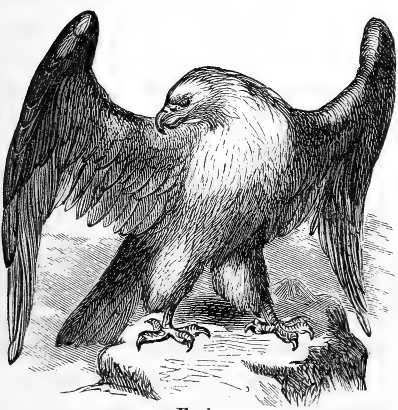
The objects of the structure of these parts may be still further illustrated and confirmed by what we observe of the size of the foot in different birds. Where the flight is limited or scarcely exists at all, the foot is small in extent, but the limb is large and strong. The muscular force not needed by the wings is transferred to the legs, and these birds are good walkers. Now this greater power in the legs enables them to balance themselves, like man, on a smaller foot, — and a small foot, it is obvious, answers for running and walking much better than a large and wide-spreading one. Thus in the ostrich, which flies not at all, but is one of the swiftest of animals on foot, the claws are only two, and quite short, while the leg and thigh are very large and powerful, at the same time that the wings are but partially developed. The same provision for violent muscular action existing in the respiration of birds, which gives to many birds their great and enduring power of flight, enables the ostrich to run so swiftly and so long. The power is in the one case directed to the wings, in the other to the legs.

These considerations show how it is that Nature has contrived to convert, as it were, the quadruped which can only walk, run, and leap, into the bird which is able to fly; and it is impossible to look at a bird upon the wing, and reflect upon the prodigious natural difficulties which it surmounts with such apparent ease, without emotions of wonder and almost of awe. The wonder indeed is greater, and the skill is greater, than if the animal had been made upon an entirely new plan, and not by a modification of that on which others are constructed. We can conceive that an animal adapted for flying might have been constructed upon a plan which avoided some, at least, of the difficulties that are surmounted in birds. It might, for example, have been made of a substance much lighter than quadrupeds, and have been, like fish, of nearly the same specific gravity with the medium in which it was to move. This would have called for a far less expense of power in order to the performance of its functions. But in this case the bird would not have corresponded with the creation in which it was placed; and would have afforded a less striking illustration of the plan pursued in the creation of the universe.

In connection with other circumstances which adapt birds for their peculiar mode of locomotion, we find that their covering is by no means an unimportant particular. Instead of hair, as in quadrupeds, their skin is generally covered with a growth of feathers; and the wings, especially, with those of a great size and strength, for the purpose of striking the air with sufficient force to raise them from the earth and bear them on in their flight. It is not necessary to describe so familiar an object as a quill. It is only necessary to remark that it combines strength with lightness in a most remarkable degree, and thus, without adding to weight, provides at once a covering and an instrument of motion. There are various other particulars relative to the structure and economy of Birds which will be hereafter dwelt upon in connection with other subjects. The scientific arrangement of this class is founded on a reference to a great many particulars in the structure and configuration of the bill, the head, wings, and feet. The most generally understood is that which divides it into six orders. These are:—

I. *Accipitres*, or Birds of Prey. These correspond, in some respects, to the carnivorous animals among quadrupeds. They are distinguished by their strong, hooked beaks, and their crooked and powerful talons, by means of which they are enabled to prey upon other birds, and upon some of the smaller quadrupeds and reptiles. They are divided into the diurnal and the nocturnal. The diurnal include the vultures, eagles, falcons, hawks, buzzards, and kites. The vultures are heavy and ferocious, feeding principally upon carrion. They are so voracious, and fill themselves to such an extent, that they become quite stupid and inactive. The eagles, falcons, &c., prefer living animals for their food, and do not prey upon carrion, unless driven to it by hunger. The number of their species is very great, and they are observed to vary considerably in their plumage, according to age and other circumstances. The females are generally a third part larger than the males, and are likewise superior in beauty of shape and plumage. Hence the latter have been often called tercets, or thirds, from their inferiority in size.

Fig. 23.



Eagle.

These birds are generally fierce and difficult to tame, but in former days, the hawk and the falcon were educated with great care, and trained so as to be employed as assistants in hunting.

The nocturnal birds of prey include only the different species of owl. They are destitute of the dignity and beauty which distinguish the diurnal. They have large heads, which are sometimes surmounted with feathers that give them the appearance of being horned. Their eyes are very large, and, unlike those of most other birds, are directed forwards, and surrounded by a rim or circle of projecting feathers. This structure is calculated to admit so much light, that the full rays of the sun dazzle and blind them; and they are capable of seeing well only in the twilight or evening. The owls are awkward and clumsy in their motions, and their wings are too short and weak for long flight. They prey upon mice and other small quadrupeds, upon birds and insects.

Fig. 24.

Great Horned Owl.

II. *Passeres*, or Sparrows, form the most extensive and numerous order, embracing a very great variety of species, which differ so much among themselves, as to be hardly capable of an intelligible description, common to them all. To this order belong those species which are most celebrated for the sweetness and harmony of their notes; and in general the organ of voice is in them larger and better formed than in any others. Among them are some that have a sharp, pointed beak, and feed upon insects, such as the blackbird, the robin, the nightingale, and the linnet; and others with a short, flat beak, and wide mouth, which enable them to catch and swallow insects, while upon the wing. These migrate during the winter; among them being the swallow, the martin, and the salangane, a species whose nests, made of a gelatinous substance, supposed to be the spawn of fishes, have been celebrated for their nutritious and restorative qualities. Some of this order have a strong, con-

Fig. 25.

Nightingale.

ical beak, feed upon seeds, and devour great quantities of cultivated grain, as the lark, the titmouse, the yellow-hammer; and some are larger birds, as the crow and the magpie, which feed also in part upon grain, but are fond of flesh, and will sometimes take and destroy mice and other small animals.

The Birds of Paradise and the Humming-Birds are also of this order. The former have been noted for the splendor of their plumage, and the profusion of long feathers with which different parts of their bodies are adorned. It was formerly believed that they were destitute of feet, and never alighted upon the earth, but were always supported in the air by their long plumage. This mistake was caused by the mode of preparing them for sale adopted by the natives of the countries they inhabit, who always deprived them of their feet and wings.

The Humming-Birds are the smallest of the class, and at the same time among the most beautiful. Their necks are clothed with small scale-like feathers of a peculiar structure, and of a brilliancy in some almost equal to that of precious stones. They have a long and slender beak, and a long tongue divided into two filaments, with which they suck the juices of flowers. They feed also upon insects. Their wings are exceedingly powerful in proportion to the size of their bodies, and they fly, comparatively, more rapidly than any other bird. They have the faculty of balancing themselves, by means of their wings, as easily as some insects, and are thus enabled to remain stationary in the air, whilst they thrust their beaks into flowers, to possess themselves of the contents. The rapid motion of their wings occasions the buzzing or humming noise with which their flight is accompanied. The smallest species of humming-bird is found in South America and some of the West Indian islands. It does not exceed an inch and a quarter from the extremity of its beak to that of its tail.

III. *Scansores*, or Climbers. This order includes those birds that have the external toe upon each side turned backward. This enables them to grasp substances more firmly with their claws, and affords them a more sure support than other birds. This structure adapts them for climbing, as they can cling with considerable force to the rough bark and branches of trees.

All birds with this form of the feet are of this order, although, strictly speaking, all of them do not climb, whilst some, belonging to others, and without this provision, do.

The birds of this order often build their nests in the holes of decayed trees. Their food consists of insects, fruits, or seeds. Among them are the woodpecker, the cuckoo, the toucan, and the parrot.

Fig. 26.

Canadian Woodpecker.

The Woodpeckers are strongly characterized by a long, straight, angular beak, narrowed into a wedge at its extremity, and thus fitted for piercing and splitting open the bark of trees; and by a long and slender tongue, covered towards its tip with spines or bristles, which are turned backwards, and coated with a thick, viscid secretion. They run in every direction around the trunks and branches of trees, striking them with their beaks, and thrusting their tongues into the holes and clefts they find in the bark, for the purpose of drawing out worms and the larvæ of insects, which constitute their food.

The Toucan is principally remarkable for the enormous size of its beak, which is almost as large and as long as its whole body. It is of a light, cellular structure, and furnished with a long tongue, straight, and armed on each side with barbs like a feather. The toucans live in small flocks in the warm parts of America. When they have seized their food, they throw it into the air, and catch it with their beaks, in order to swallow it with more ease, as they are incapable of masticating it.

IV. *Gallinaceæ*, the Gallinaceous birds. Of this order are the peacock, the turkey, the common fowl, the pheasant, the partridge, the quail, and the pigeon. Among them are nearly all those birds which have been domesticated, and are raised in poultry yards. Their wings are short and weak, and of course they are not constructed for long-continued flight; but they are capable of running with considerable rapidity. They have a large crop and a very powerful gizzard, their food consisting principally of hard grain. Their flesh in general furnishes excellent food. The males are distinguished by a stately gait, and frequently by a tail ornamented with long feathers. They do not all live in pairs; their eggs are very numerous, and are laid in nests built of chaff or straw upon the ground. Their young are generally able to run about as soon as hatched.

Fig. 27.

Passenger Pigeon.

The Pigeons form in some particulars an exception to the general characteristics of the gallinaceous birds, and approach to a resemblance to the Passeres. They fly very well, live in pairs, build their nests upon trees or in the clefts of rocks, and produce seldom more than two eggs at once. Their young are at first nourished by a substance brought up from the crop of the parent, supposed by some to be the food partially digested, and by others a peculiar secretion from the organ, analogous to the milk of mammiferous animals; probably it is a mixture of them both. The most remarkable species among them is the crowned pigeon of the Molucca islands, which is equal in size to a turkey. Its voice is exceedingly loud and harsh, and is said to have frightened sailors, who landed on the islands it inhabits, by its resemblance to the yells of the savage natives.

V. *Grallæ*, the Waders, otherwise called Shore Birds. They are distinguished by their very long and naked legs, which permit them to wade to a considerable depth in the water without wetting their feathers. The length of their neck and beak corresponds to that of their legs, and they are consequently able to search in the sand and mud at the bottom of the water for their food, which consists of fishes, reptiles, and worms. All birds with this structure of the legs are ranked among the Grallæ, although some of them are not, properly speaking, waders in their habits. To this order belong the ostrich, cassowary, flamingo, heron, spoonbill, plover, rail, woodcock, ox-eye, yellow-leg. The greater part of them are possessed of strong wings, and fly well, but the ostrich and cassowary, as is well known, are striking exceptions. They are almost incapable of flight, but run with immense rapidity. The ostrich inhabits the sandy deserts of Africa, attains to a height varying from six to eight feet, and is at once the most lofty of birds, and the swiftest of all animals. When chased, it annoys its pursuers by throwing up gravel and stones behind it with its feet.

Fig. 28.

American Flamingo.

VI. *Anserés*, the Web-footed birds. Their toes are connected together by a web or membrane, which fits them for being used as oars. Indeed, the whole structure of these birds is such as to adapt them for swimming. Their legs are situated far back upon their bodies; their feathers are thick, smooth, and oily, and the skin beneath covered by a layer of close down, which effectually protects them from the contact of the water. Their necks are of considerable length, — a provision which enables them, while swimming upon the surface of the water, to plunge their heads down to the bottom in

Fig. 29.

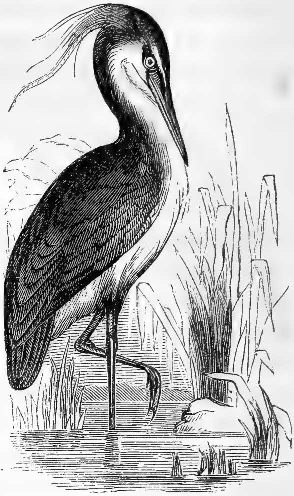
Wild Goose.

search of food. Most of them are capable of a lofty and long-continued flight, as the pelican, petrel, cormorant, albatross, swan, wild goose and duck; whilst others, from the shortness of their wings, can scarcely raise themselves into the air, but are principally confined to the surface of the water, as the sea-diver, guillemot, penguin, and the auk.

There are some points of comparison between the several orders of Birds which are worthy of notice in connection with the views that have been already presented, and which serve further to illustrate them. The Accipitres (Fig. 23), for example, require great strength in the head, neck, and claws. These are accordingly short; for were the neck long, like that of most birds, with a large and strong head at the end of it, it would require an undue proportion of muscular power to manage it. The same is true of the claws and legs. They are short or they could not have been strong; and in seizing and carrying away their prey they derive a great advantage from the mechanical contrivance formerly alluded to, which fixes them involuntarily to the roost while sleeping. When an eagle seizes his prey and wishes to rise with it into the air, he draws the body downward on the legs. This occasions the firm grasping of it by his talons, and he thus lifts and carries it off without any special care.

With the Accipitres may be contrasted the Waders, Grallæ, or Shore Birds. These are also birds of prey, but of so different a kind that they require a different structure. Their prey consists of animals that make little resistance and require no great strength to conquer, namely, animals inhabiting the water. They agree with the Accipitres in their great powers of wing, but stand at the opposite end of the scale in the conformation of their feet, legs, and neck. These are long, enabling them to wade in the water and then seize on their food at the bottom. The Accipitres require strength, without length of neck and legs, the Waders, length without great strength, in order to secure the prey on which they respectively feed. But although the Waders do not require strength to seize on their prey, they do need a power of standing for a long time in order to watch for it. Were this done by muscular power, their limbs must have been large and heavy, and thus the balance necessary to flight be destroyed. To avoid this there

Fig. 30.



Heron.

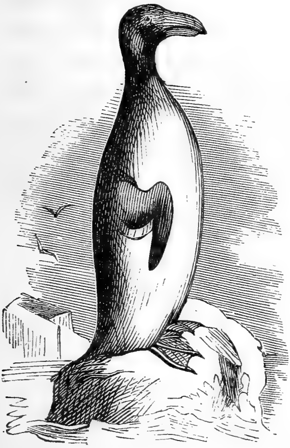
is a simple contrivance at the knee-joint, by which the bones are as it were bolted together. They can thus stand a long time, even on one leg, without fatigue; and sometimes, when standing on one foot in the water, they hold a stone in the claws of the other to steady themselves against the motion of the waves.

Strength for standing can thus be given, but not strength for moving. Hence in the ostriches and cassowaries — which are like the Waders in their general shape, but differ entirely in their habits, being intended to run instead of flying — the legs are not only very long but also very strong and large and endowed with an immense quantity of muscular substance.

These form a link between the Waders and the Gallinaceous birds, the peacock, turkey, and common fowl. In these the powers of motion are more equally distributed between the wings and legs, though the advantage is in many in favor of the latter, especially when domesticated. But in the Passeres or Sparrow tribe, who are both good flyers and good walkers, but not remarkable in either respect, — though to this there are some exceptions, — there is a more equal division of power. Among the Climbers, too, the powers are very equally divided; but in the Palmipedes or web-footed birds a very different arrangement is necessary in the relative construction of the neck and legs.

The neck is longer than the legs and sometimes very much longer, and the latter are placed very far back in the body for the convenience of swimming. The long neck answers the same purpose as in the Waders, namely, to enable them to seek their prey at the bottom of shallow waters, over which, however, they swim, instead of wading through. In proportion as they are more perfectly adapted for swimming they are less so for walking, but not for flying, because the apparatus for flying is not interfered with by the provision for swimming, whilst that for walking is. Hence they are notoriously awkward on land, though they are capable, many of them, of long flight, and move with great beauty and grace upon the water. They find it extremely difficult in walking to preserve their balance, and are only enabled to do so by throwing the body back upon the heels and arching the neck backward, so as to bring the weight of the head but little in advance of the body.

Fig. 31.



Auk.

In consequence of their peculiarities of structure, some of the birds of this order can maintain themselves on land only in a sort of erect posture, — not like the gallinaceous birds on the toes, but by throwing themselves backward and resting upon the whole of the shank. They can hardly move upon land at all, and do not even have the power of flight, their motions being almost exclusively confined to the water, where, however, they swim and dive with great perfection, their stumps of wings serving the purpose of oars. Such are the guillemots and auks.

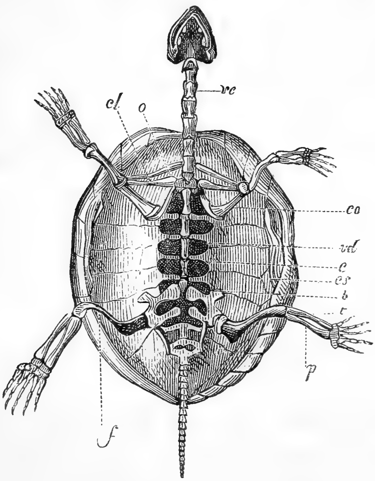
SECTION III.

CLASS III. — REPTILES.

The class of Reptiles, including the tortoises, lizards, serpents, toads, and frogs, have cold blood, and a circulation and respiration less perfect than those of the preceding classes. In Reptiles, only a part of the blood received from the body by the heart is sent to the lungs, to be subjected to the influence of the air; whilst the remainder, having been mixed with a portion which has undergone the change that takes place in respiration, is returned again into the circulation. The first three orders of the animals of this class have two auricles to the heart, but only one ventricle: into the left auricle, the red blood from the lungs is poured, and into the right, the black blood from the body. From the auricles, the two kinds of blood are immediately transferred to the ventricle, where they are mixed together; and this mingled mass is, by the contraction of the ventricle, sent through two distinct vessels, in part to the lungs, and in part to the body.

The vessels of Reptiles, then, are not filled with pure red blood, like those of the Mammalia and Birds, but with an imperfect fluid, not so well adapted to give them a high degree of life and vigor. Hence, as the animal heat is always in proportion to the quantity of respiration, they are cold-blooded. Their lungs are not so large; their circulation is more languid; they consume less air, and are capable of living for a longer time without it. They are, in general, sluggish and indolent in their habits of life, obtuse in their sensations, and slow in their digestion. In cold

Fig. 32.



Skeleton of Tortoise.

In this figure, the lower shell is removed so as to display the principal parts of the internal skeleton.

vc, vertebræ of the neck; *vd*, of the back; *c*, ribs; *cs*, sternal ribs or marginal pieces of the carapace; *o*, scapula; *cl*, clavicle; *co*, coracoid bone; *b*, pelvis; *f*, femur; *t*, tibia; *p*, fibula.

countries, they pass the greater part of the winter in a dormant state. Their brain is small, and their nervous system imperfect and of less influence than in the preceding classes. They produce their young by means of eggs, but take no pains themselves to hatch them. They have less intelligence, fewer faculties, and less instinct, than either quadrupeds or birds. They are arranged in four orders.

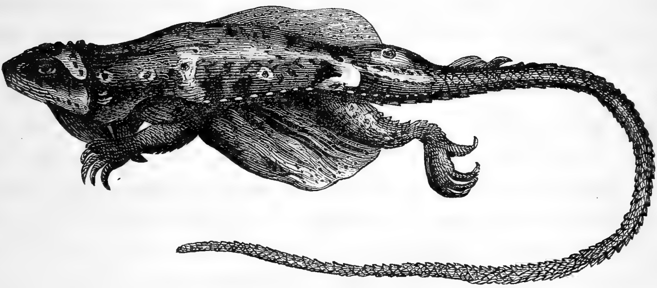
I. *Chelonia*, the Tortoises, are distinguished by the peculiar structure of their ribs, sternum, and vertebræ. These are so arranged as to form a complete covering, consisting of an upper and under shell, joined together at their sides; which permits only their head, tail, and four extremities, to be extended without it. The upper shell is formed by the extension and enlargement of the ribs and part of the backbone, and the lower shell by an alteration in the form of the sternum; called respectively the *carapace* and *plastron*. These parts are, however, covered by a substance of a horny texture, known familiarly as tortoise or turtle shell, and entirely different from bone in its nature and texture. Their other bones are not essentially different from those of other vertebral animals. Thus a part of their skeleton is, in fact, on the outside of their bodies. They have no teeth; but their jaws are armed with a tough, horny substance, which supplies their place. Their stomach is simple and strong; their intestines are long, and they are capable of going a great length of time without food. All the various species of the tortoise and turtle belong to this order.

II. *Sauria*, the Lizards. This order includes a very considerable variety, among which are the crocodile, the alligator, the chameleon, the true lizards, and the dragons. The greater part of them have four feet, but a few are possessed of only two. They have nails and teeth, and their skin is covered with scales.

The Crocodile is the most celebrated animal of this order. It is from twenty to thirty feet in length, including the tail, and is covered with a coat of scales, which, on the back, form an armor proof against a bullet, and have an appearance like that of carved work. It deposits its eggs in the sand, where the greater part of them are destroyed by birds and an animal called the ichneumon. Their eggs resemble, a good deal, those of the domestic goose, and are of about the same size; the young, when first hatched, are of course very small when compared with the parent animal. They are at first mild and innocent, and may be handled with impunity; but the full-grown animal is both subtle and formidable. It lies in wait, covered from view amidst long grass, rushes, or projecting banks of rivers, until some animal comes within its reach, which it seizes and swallows, and then retires to some secret recess to digest.

The Dragons are remarkable for the possession of a sort of wings, produced by the extension of the first six false ribs, which support a fold of the skin. These serve, like a parachute, to uphold them in leaping to the ground from any height, or in springing from branch to branch on the trees they inhabit; but are not sufficiently large or powerful to enable them to raise themselves from the earth.

Fig. 33.



Flying Dragon.

To Chameleons has been attributed the singular faculty of changing the color of their skin, according to the color of the substance on which they are placed, and of subsisting upon air. This belief has arisen from the extraordinary size of their lungs, which they are capable of distending with air to such an enormous extent as to fill nearly their whole body and render their skin somewhat transparent. Hence they were said to feed upon air. In this state of distention and semi-transparency, the skin becomes easily affected by every change in the circulation; and consequently a change of color is produced by the varying wants and passions of the animal, which influence both the quantity of respiration and the tint of the blood.

A few animals of the lizard kind are remarkable for their very short legs and long slender bodies, giving them the appearance of serpents with feet, for which they have sometimes been mistaken.

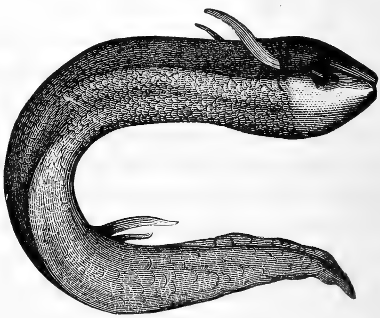
III. *Ophidia*, the Serpents, are distinguished by their long and slender bodies without limbs, and by the great extensibility of their jaws, mouth, and throat, which enables them often to swallow animals of greater diameter than themselves. They are always provided with teeth, which are sharp and bent backwards.

Among them, as is well known, are the venomous and those that are not venomous. The number of the latter kind is the greatest, and includes the largest animals. Among them are the great boa-constrictor, the aboma, and the anaconda, which sometimes attain the length of thirty or forty feet, and inhabit marshy and fenny places in the tropical parts of America. They attach themselves by the tail to the branches of trees, leaving their bodies swinging in the air, in order to seize upon animals approaching them, which they generally swallow whole. The Ular Sawa, or the great Python, is another serpent of the same kind and size, and inhabits the ancient continent. The smaller and less celebrated species are very numerous, and are distributed over every part of the earth.

The venomous serpents are armed with pointed fangs, for the specific purpose of infusing poison into the wounds they inflict. These are situated in the upper jaw, and perforated by a small canal, which, opening on their extremities, gives passage to a fluid secreted by a gland under the eye. When the tooth pierces the flesh of any animal, a portion of this fluid is injected into the opening, and produces effects more or less dangerous, according to the virulence of the poison and the kind of animal wounded. When broken or injured, these fangs are renewed, and when not employed, are hidden from sight by a fold or projection of the gum. The largest and most celebrated of these animals is the rattlesnake of America. It is so called from a peculiar instrument at the end of its tail, denominated its rattle, which produces a slight rustling sound when it is shaken, and is intended to give warning of the animal's anger. This and the other venomous serpents are not malignant or ferocious in their dispositions, and seldom make use of their poison unless provoked.

IV. *Batrachia.* The reptiles of this order have only one auricle to the heart, into which the veins from the lungs and from the body both enter. In it are included the toad, frog, salamander, and other similar animals. They are principally remarkable for a transformation which takes place in their offspring after leaving the egg. When first hatched, they are strictly aquatic, and capable of breathing and living only under water. They are furnished with gills like a fish, and have no legs, but are provided with a tail, which serves them as an instrument of locomotion. In this state they are seen by thousands, of a dark color, with round bodies, swimming about in brooks and small ponds; and are known by the familiar name of tadpoles. After a certain period, their form and structure are altered: their feet and legs grow, and project from beneath the skin; their tail, their gills, and the covering of the head, fall off; they begin to respire by means of lungs; and become, at length, animals capable of breathing only in the air. This transformation is not, however, in all cases complete. In several genera, the proteus, the siren, and some others, besides lungs, the gills are retained through life, and they are thus possessed of two distinct sets of organs of respiration.

Fig. 34.



Lepidosiren.

These form a link between reptiles and fishes; and in one of them, the lepidosiren, it has been difficult for naturalists to satisfy themselves to which class the animal belongs.

SECTION IV.

CLASS. IV. — FISHES.

In studying animals with a view to understand the relations of their structure to their mode of life, Fishes form an object of much interest, since, like Birds, they live in a medium *in* which they are supported, and *through* which they make their way by the action of their limbs, whilst the Mammalia and Reptiles are chiefly designed for a residence and motion *upon* a solid basis. But as there is a great difference in the density of the mediums in which Birds and Fishes respectively move, so is there a great difference in the provisions of structure by which they are adapted to them. Birds move through air, which is many times lighter than their bodies; Fishes through water, which is of about the same specific gravity with theirs. The principal labor of birds is to raise and keep their bodies in the air. Progressive motion requires little additional force, because the air presents little resistance. But in fishes the condition of things is exactly opposite. They require very little effort to keep themselves suspended in the water, whilst this fluid offers a considerable resistance to their progressive motion. In the bird then, as we have seen, the peculiarities of structure are chiefly devoted to overcoming the force of gravity. In the fish, they are chiefly devoted to overcoming the resistance of the water to progressive motion.

But in birds the amount of muscular power required for the maintenance of their peculiar function is very great, whilst in fish it is comparatively small. Their shape is such, and their organs of motion so arranged, as to overcome the resistance of the water with the smallest possible muscular power. If we compare the organs of motion in the two classes, we find a striking difference in their extent. The fin and tail are the chief in fish. They expose a very small surface compared with that of the whole body; probably not a quarter part. But the wings of birds of long flight present perhaps twenty times the surface of that of theirs. This remarkable difference in the position and relations of these classes, might be followed out in much detail, and we should everywhere find the same exact correspondence between them and the structure by which they are accompanied.

It was formerly pointed out that where there was a great amount of muscular power, this was to be supported by a corresponding energy of respiration and circulation. For the same reason, where there is a low degree of muscular power, a lower energy in these functions will accompany it. Accordingly, Fish have a far less energetic and complete system of circulation and respiration than Mammalia and Birds. Their heart has but a single auricle which receives the blood from the body, and a single ventricle which then sends it to the gills or organs of respiration. When returned from the gills, it is collected into one large vessel, not terminating in a heart as in Mammalia and Birds, but assuming the office of an artery, and distributing its contents to the whole body.

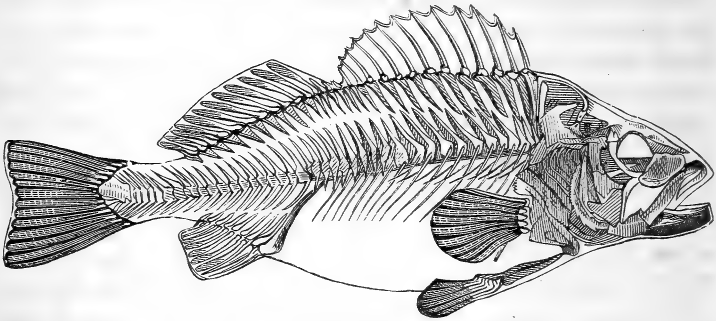
The gills are vascular bodies, situated on each side of the neck, with whose appearance most persons are sufficiently familiar. Just between them is the single heart, which after receiving the venous blood from the body, circulates it through them. A current of water is made to pass constantly over their surface, and to the air in this water the blood is exposed, and undergoes the same change as that which is effected in the lungs of the preceding classes.

This motion goes on as regularly as the action of the chest in respiration, and the current of water may be readily observed in the goldfishes that are confined in glass vessels. Any interruption of it is attended by the same fatal consequences as a suspension of the admission of air into the lungs, and if it be arrested by mechanical closure of the gill-opening, the animal falls into convulsions and soon dies.

The skeleton of Fish departs more from the original model of the vertebral animals than that of either of the preceding classes. The vertebral column, however, is still the basis of the whole. There is a bony cranium for the brain, and the same senses are performed by organs situated in and around it, as in the higher animals.

The bones which support the fins correspond also to the four extremities. The pectoral to the upper, and the abdominal to the lower. There are, also, others, varying in different species;

Fig. 35.



Skeleton of Fish.

but, with the exception of the caudal or tail fin, they serve rather to balance and regulate the position and motions of the animal, than to move it forward. In the tail and its fin is concentrated a great share of the muscular power of the body, and with this, as in a boat moved by a single oar, as in sculling, progressive motion is chiefly effected.

An organ called the air-bag, or swimming-bladder, exists in a majority of fishes, but not in all. It is situated in the cavity of the body just underneath the spine. It is filled with air containing nitrogen and oxygen, but not in the same proportions as in that of the atmosphere. These proportions are found to vary according to the depth at which the animal resides. Those near the surface have more nitrogen, and those from deep water more oxygen. The cause and purpose of this difference has not been sufficiently explained.

This structure seems to have some connection with the moving powers of the animal, yet its precise function is not perfectly understood. It is commonly supposed that by the compression or expansion of the air in this sack, the animal is enabled to rise or sink without any muscular effort, by the mere variation thus produced in its specific gravity. This view has seemed to be confirmed by the fact that if the air-bag be punctured the animal sinks to the bottom and cannot rise again, and that certain species which inhabit chiefly the bottom of the water, as the flat-fishes, sole, flounder, &c., and those of the ray and skate kind, are destitute of the organ.

But there are other circumstances which throw some doubt upon this view of its function. Some species living for the most part at the bottom, as the eel, have it, and others capable of a great variety of motion, at all depths, have it not, as the shark and mackerel. It is obvious, too, that, even were a fish able to descend by condensing the air in its bag so as to increase its specific gravity, when arrived at the bottom the pressure of the water would prevent entirely such a dilatation of it as would diminish that gravity, so as to enable it again to reach the surface. So, too, when fish remain near the surface in a warm day, the confined air becomes so rarefied that they cannot descend; and on the other hand, when drawn up from a great depth, the sudden removal of the pressure to which they have been subjected produces a similar expansion, so as in some instances to force the stomach out of the mouth, by the distention of the air-bag. Both these facts are incompatible with such a power of dilatation and contraction on the part of this organ as the office attributed to it requires.

There are thus objections which seem insurmountable to the ordinary explanation of the use of the air-bag. Is it not worthy of inquiry whether it may not be intended to keep the body of the fish in which it is found in a vertical position, with the back upward? The greater number of Fishes are of so compressed a shape that from simple physical causes they would take a position on the side, or if the abdomen be lighter than the back, upon the back. In fact it is stated by Cuvier, that, if the air-bag be punctured, the animal will turn upon its back, and can assume no other position. The air-bag, then, may be intended to answer the purpose of ballast. A light body placed above the centre of gravity will answer the same purpose as a heavy body placed below it. Thus it corresponds in its purpose to the keel-shaped projection of the sternum in Birds, and the heavy mass of flesh attached to it, which serve in them to keep the body properly balanced beneath the wings. There is another view taken of the uses of this organ, which considers it as supplementary to those of respiration, and as giving aid in the aëration of the blood. Even were this so, it would not necessarily exclude the exercise of the office above attributed to it; since there are other instances in which Nature avails herself of the presence of an organ intended for one function, to assist in the performance of another, — as the lungs, though mainly intended for the introduction of air for the service of the blood, also contribute in a secondary manner to the production of the voice.

Fishes have a thick, strong skin, which in many is of a hard, bony structure, but in the larger proportion is covered with scales, which are arranged one upon another in an imbricated form, like slates or shingles on the roof of a house. Their bodies are also invested with a covering of thin mucus, or slime, which defends them from the immediate contact of the water. Their forms vary exceedingly, and are much more numerous than those of the animals heretofore described. They vary also in size. Some are armed with strong, sharp spines; some with a sword or saw; and most of them with teeth. The latter, however, are not intended for the purpose of chewing, but merely for that of seizing and retaining prey, which is swallowed whole. A few are possessed of a very remarkable species of defence, which consists in the power of inflicting upon whatever living creature comes in contact with them, an electrical shock.

Fishes have but a small brain. They have the senses of seeing, hearing, smelling, and tasting. That of touch they probably possess but imperfectly, as they have no organ which seems intended for its exercise, except the snout and mouth, and in some species, a sort of feelers, growing around the mouth. Their skeleton is constructed of bones, softer and less earthy than those of other animals, and indeed in some they are entirely cartilaginous. Their stomach and intestines are formed upon the same general plan with those of the other vertebrals, and digestion is carried on in the same general way. They feed principally upon other fishes, upon worms, and shell-fish. They are long-lived, attain to their full growth slowly, and exhibit but few signs of intelligence or remarkable instinct.

Their constant residence in the water prevents that accurate knowledge of their character and habits of life, which would afford materials for a more copious detail. They are divided into orders and genera, according to certain differences in the formation, structure, and situation of their mouth, gills, gill-covering, fins, &c.

CHAPTER VII.

SECOND BRANCH OF THE ANIMAL KINGDOM. — ARTICULATA, OR ARTICULATED ANIMALS.

Of the classification of this and the two other grand divisions of the animal kingdom, it will not be necessary to give a detailed account, since, with the exception of the class of Insects, the principal illustrations of our subject will be derived from the Vertebrata.

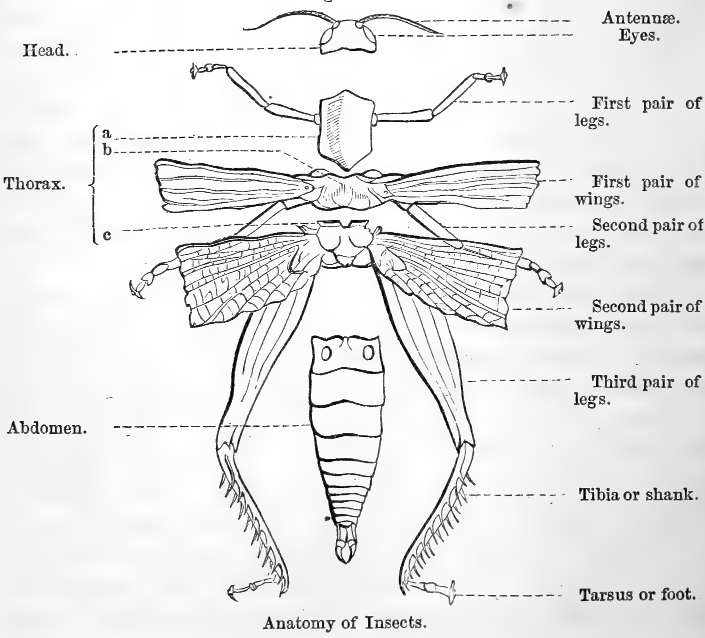
This class, — namely Insects, — constitutes one of the most interesting in the whole living creation. The number of distinct species is probably as great as that of all other animals put together. As we shall have occasion to see hereafter, we find among them the most remarkable exemplifications of directing instinct. At the same time they are of the utmost importance in various ways in carrying out the purposes of Providence in the great scheme of Nature.

Insects are destitute of a heart, but instead of it they have a canal or reservoir situated along the back, extending from one end of their bodies to the other, and filled with a transparent, viscous fluid. This undergoes an irregular contraction, which is supposed to be analogous to the contractions of a heart. But there is still no such regular system of vessels connected with it as exists in the preceding classes. We cannot, however, doubt that this reservoir is supplied with its contents from the digestive organs, and that it sends them by its contraction to all parts of the body. Insects have no particular organ for respiration, but their bodies are penetrated in all directions by tubes, called tracheæ, which convey the air to every part. These tubes communicate externally by openings called stigmata. The blood, therefore, undergoes the changes wrought upon it by air, throughout its whole circulation. Instead of a brain and nervous system, they are furnished with two knotted cords, running the length of their bodies, which perform the same functions. They possess the senses of seeing, tasting, smelling, and feeling; but organs of hearing, if they exist, have not yet been certainly recognized.

Being destitute of any internal skeleton, Insects are provided with a firm external covering, which serves to support their motions and protect their organs. The nature of this covering differs in different species; in some it forms a complete shell or case of a horny or shell-like substance; and in others it consists merely in a tough, muscular coat, divided into rings, which surrounds the body.

The greater part of Insects are winged, but some are not so.

Fig. 36.



Anatomy of Insects.

Those which are not winged continue, during their whole existence, of the same form and structure as at birth. Those which are winged undergo certain metamorphoses, or changes of form, to be hereafter described. They have six legs, with the exception of the millepedes; these have always more.

The bodies of Insects are divided into head, trunk, and abdomen. The head is attached to the trunk by a joint or articulation, movable in every direction. It is destitute of a brain, but is furnished with a mouth, eyes, and two antennæ or feelers. These are a kind of filaments, composed of joints, varying much in form and length, probably designed as the organs of the sense of touch, perhaps of hearing, or of sensations still more delicate, but of a nature totally unknown to us.

The mouth of Insects varies much in its construction, according to the nature of their food. Some of them subsist only upon the juices of animal and vegetable substances, and have their lips arranged in the form of a tube or sucker; some of them are armed with a sort of lancet, with which they are enabled to pierce the skin of animals; some with a kind of beak; and others with a trunk or proboscis, which in the butterflies is capable of being rolled up in a spiral form. The insects that subsist upon solid substances are provided with jaws, which act laterally instead of vertically, and serve to masticate their food. Beside these parts, many species are furnished with *palpi*, organs somewhat resembling the antennæ in structure and appearance, but whose office is to bring the food to the mouth, and hold it, while the animal eats.

To the trunk are joined the legs, and the wings when present. It is divided, in those that have only six legs, into three segments or divisions, to each of which one pair is attached. The legs are composed of four parts, called the haunch, thigh, leg or shank, and foot; which resemble somewhat the corresponding parts in the limbs of quadrupeds. They vary in different insects, according to their habits and modes of life. Thus, in the grasshopper, the hind pair are very long and strong; in the aquatic insects, they are flattened, in order to answer the purpose of oars. The wings differ much in kind and arrangement, as well as in number. Most of the winged insects have four, but some only two. They are generally thin, dry, membranaceous, and semi-transparent. In the butterfly the membrane forming the wing is concealed by a covering of small scales, which appear to be merely a loose powder, but are in fact fixed by small pedicles or stalks to the membrane itself. They give to those insects their beauty and variety of color. The insects with one pair of wings have underneath them two cylindrical projections terminating in a knob, which seem as if they were the rudiments of a second pair. These have been called balancers or poisers, from being supposed to aid them in preserving an equilibrium during their flight. Between them and the wings themselves are found small membranous scales, one upon each side, against which the balancer strikes with great rapidity whilst the insect is in motion, and causes that buzzing which is then observed. In the various kinds of beetle and other similar insects, the upper pair of wings is of a crustaceous or horny texture, and serves merely the purpose of a case under which the other pair is folded up and protected. In others, as in the grasshopper and the locust, the upper pair is less hard, and has rather the consistence and texture of vellum.

The abdomen forms the hinder part of the bodies of Insects; it contains the organs of digestion, and is the part from which their eggs are produced. It is divided into a number of rings or segments. In some, it is furnished with a perforator or auger, with which various substances are bored in order to admit their eggs. In many it is terminated by a sting, as in the wasp and bee, and in others by a forceps, a bristle, or a claw. They display much instinctive intelligence in the deposition of their eggs, placing them in situations best adapted to the nourishment and preservation of their young when hatched, and in some cases even providing food for their immediate wants when they first come into life.

The greater part of Insects, as has just been remarked, after leaving the egg, undergo certain changes of structure and form, before arriving at their perfect state. These changes are called their metamorphoses. They differ in number in different kinds of insects.

To take the Butterfly tribe for an example. From the egg of this insect is hatched an animal differing entirely from its parent. Its body is long and cylindrical, and divided into a great many rings. It is provided with a large number of very short legs, with jaws, and with several small eyes. It is familiarly known to us by the name of *caterpillar*. It lives in this state a considerable time, subsisting upon such food as is adapted to its nature. At length it casts off its skin, and appears in another form, without limbs. It ceases to feed or to move. It seems to be totally without life. This is called the *chrysalis*. After a while, by examining it closely, the imperfect shape of the butterfly may be distinguished through its surface; and finally the envelope is broken, and the animal escapes. Its wings are at first weak and moist, but they soon unfold and become strong; and the insect is in a state to fly. It has now six long legs, a spiral trunk, two antennæ, and eyes differing entirely from those of the caterpillar. In short, it is a totally different animal; and yet these wonderful changes are only the successive unfolding of parts contained one within another in the original embryo.

In the first state, the animal is called the *larva;* in the second, the *nympha* or *chrysalis;* the third is called the *perfect state.*

A considerable proportion of the insect tribes pass through these three stages of existence. But many only undergo what is called a demi-metamorphosis. The larvæ resemble the perfect insect, except that they are without wings. And the only change they experience is, that in the nymph state they have stumps or rudiments of wings, which finally, on casting their skin, are exchanged for complete ones. Such are grasshoppers and many kinds of bugs. Insects without wings undergo none of these alterations.

An account of some analogous phenomena occurring in other animals will be found in a subsequent part of this volume.*

There are few vegetable substances which escape the depredations of Insects; and sometimes their ravages produce very serious evils. Good as well as evil, however, may be attributed

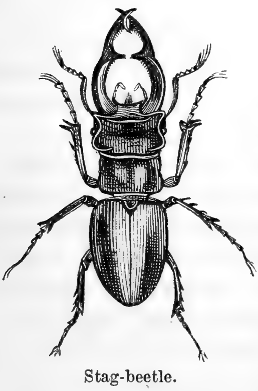
* See chapter on the Reproduction and Transformation of Animals.

to their agency. Many of them feed upon putrid animal or vegetable matters, whose effluvia might otherwise become dangerous or fatal. Others are made use of in medicine, in the arts, and sometimes even as food for man. They serve as nourishment for many species of animals. Beasts, birds, reptiles, and fishes, equally make them their prey; and thus prevent their multiplication to such an extent as to prove a permanent evil to mankind.

It only remains to give some general account of the orders under which Insects have been arranged, and the principles upon which naturalists have proceeded in making the distribution of them.

The following are the divisions of this class into orders as established by Linnæus. They are retained, not as affording a sufficiently accurate arrangement for the special study of Entomology, but as presenting a more intelligible view of the various forms of insect life than the general reader would obtain from the more detailed and strictly anatomical methods of modern naturalists. They are founded upon the presence or absence of wings, their number, their texture, their arrangement, and the nature of their surface; and upon the existence or absence of a sting. He forms seven orders.

Fig. 37.



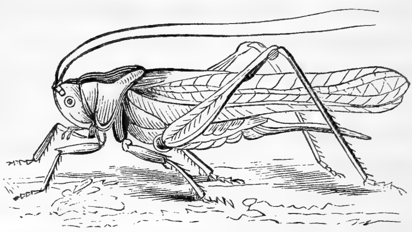
Stag-beetle.

I. *Coleoptera.* The upper pair of wings in the Coleopterous insects consist of a crustaceous or horny substance. These cover and defend the other pair, which are of a more soft and flexible texture, and are folded beneath them. This is the most numerous and best known kind of Insects; and many of them are very remarkable for the singularity of their forms and the beauty of their colors. It includes the various species known under the names of beetles, winged bugs, &c. They all undergo a complete metamorphosis.

II. The *Hemiptera* have likewise four wings; but the outer pair are not of so hard a texture as those of the Coleoptera.

They are more like fine vellum, and, at their extremities, terminate with a membranous edge, which resembles the substance of the under pair. Insects of this order undergo only a demi-metamorphosis. Among them are found the grasshopper, the cricket, the locust, the cockroach, and many kinds of bugs.

Fig. 38.



Grasshopper.

III. The order *Lepidoptera* contains the various kinds of butterfly, sphinx, and moth. Those of the first kind fly in the daytime; those of the two other kinds only in the night. They all have four wings, the structure and appearance of which have been alluded to. Among them are some of the most beautiful and splendid of insects, and they form the richest ornaments of the cabinet of the naturalist. They all pass through a complete series of metamorphoses; and their larvæ, known under the name of worms or caterpillars, spin webs for their covering while in the chrysalis state. It is from the web, thus prepared by the silkworm for its residence during this dormant state of existence, that the silk of commerce is prepared.

Fig. 39.

Butterfly.

IV. *Neuroptera.* This is another order with four wings. They are membranaceous, naked, and so interspersed with delicate veins that they have the appearance of a beautiful network. The tail of the Neuroptera has no sting, but that of the male is frequently furnished with a kind of forceps or pincers. Of this order are the various species of dragon-fly, large and well-known insects that frequent lakes and pools of stagnant water, in which the female deposits her eggs; of the ephemera, insects which pass two or three years in the states of larva and chrysalis, but whose existence, as winged and perfect insects, is limited to a single day; the ant-lion, and the termites: the former is known as the destroyer of the common ant, and the latter for

Fig. 40.

Dragon-fly.

the ravages they make, in the state of larvæ, in some tropical countries. The Neuroptera do not all pass through a complete metamorphosis, a portion of them undergoing only a partial change of form.

V. The *Hymenoptera* have four naked membranaceous wings, but they have not that delicate, netted structure which belongs to the last order. The bodies of the females are terminated by a borer or perforator, or by a sting. These insects all undergo a complete metamorphosis. The ant, wasp, and bee belong to this order. There are, in the domestic economy and mode of propagation of these animals, circumstances which excite our admiration and astonishment. They live in societies, greater or less in extent and number, and prepare habitations and nourishment for themselves and their offspring, with a forethought and provident care excelled only by those of man himself. In some of the tribes of these insects, as among the ants and bees, there is, beside the males and females, a third sort, called neuters. Sometimes the neuter, and sometimes the female, is without wings, and sometimes without a sting. A more particular account of their economy will be given hereafter.

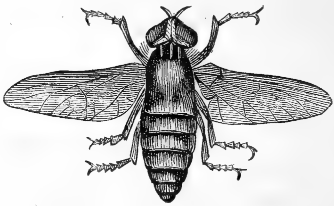
Fig. 41.

Honey Bee. Worker.

Besides the above-mentioned, there is found in this order a variety of singular animals; and among others, the ichneumon-fly and the saw-fly, which, by means of their instruments for boring, in some constructed in the form of a saw, insert their eggs in the wood, leaves, and fruit of plants, or in the eggs, larvæ, or nymphæ of other insects.

VI. The *Diptera* have only two wings, but beneath them are the balancers or poisers, which have been already mentioned. Their mouths are frequently armed with lancets and suckers, by means of which they pierce the skin of animals and feed upon their blood. To this order belong some of the most troublesome and annoying of the whole animal creation, namely, the various species of gnat and gad-fly, the mosquito, the common house-fly, and the horse-fly. They attack both men and other animals, and are found in almost every part of the globe. Their larvæ are deposited in the skins and intestines of brute animals, sometimes even in those of men, in putrid meat, in cheese, in manure, in water, and in mud. They pass through a complete metamorphosis.

Fig. 42.



Gad Fly.

VII. *Aptera.* In this order is included a great variety of insects destitute of wings. It is true that in the preceding orders are arranged many sorts of insects which are destitute of wings; but they are so arranged, because, in their general structure and habits of life, they resemble the other members of the order. The Aptera, however, have no such resemblance, and are therefore placed by themselves. Some naturalists divide them into several orders, according to their natural connections with one another; but this is not necessary here. Among them are found the centipedes, whose body is divided into a great number of rings, each of which serves for the attachment of one or more

6

pairs of legs; the louse, of which there are many kinds infesting the bodies of men, inferior animals, and plants; the puceron, &c. Some of these last animals cover the surface of plants so completely as to produce the appearance of a diseased change of structure. The flea also belongs to this order.

Fig. 43.

Scorpion.

The family of the Arachnides, or Spiders, is not always arranged among Insects, and, strictly speaking, their structure is different in some important particulars. We shall, however, give some account of them in connection with the Aptera, among which they were included by Linnæus. This family comprehends, besides the common spiders, the scorpion, the tarantula, the crab-scorpion, the various species of mites, and the animal which has been supposed to cause the psora or itch, by insinuating itself beneath the skin.

They are distinguished from all other insects by the absence of the antennæ. A part of them breathe like Insects by means of tracheæ distributed throughout their bodies; while in the rest, the tracheæ open into pulmonary sacks, which answer the purpose of lungs. In the latter, there is found a well-organized heart and a vascular circulation, which are absent in the former. They have generally eight legs, and are furnished with six or eight eyes, which enable them to perceive objects in several different directions at once. They are nourished generally by living prey, and are provided with means for securing and destroying it. The Spider effects this by means of the web that it spins, in the construction of which much ingenuity is often manifested. The threads of which it is composed, are produced from six small, fleshy bunches, situated at the lower extremity of their bodies, which are perforated with an immense number of little holes. By means of their webs, many species of spiders, particularly when young, are able to transport themselves to a considerable distance through the air. In order to effect this, they ascend some eminence, and throw out a number of webs; these are raised up and carried along by the wind, and the animal, being buoyed up by them, is conveyed sometimes to a great height. In order to alight, they have only to disengage themselves from a part of their web, and suffer themselves to descend gradually to the ground. It is probable that they have recourse to this expedient, in part at least, for the purpose of catching insects for food. In autumn, the air is often full of the cobwebs which have been made use of for this singular mode of conveyance; and those who have ascended eminences for the purpose of observing this phenomenon, have frequently seen spiders floating by in the air, supported in the manner just now described.

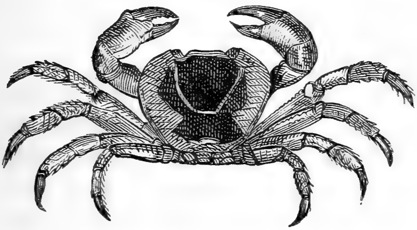
Many branches of this family are exceedingly cruel and ferocious, not sparing even their own species. The bite of some of them is poisonous, particularly that of the tarantula and the scorpion. They undergo no metamorphosis, but shed their skins several times. A few receive an additional pair of legs at some time after birth.

The Crustaceous animals constitute another group of the Articulata, and have been sometimes included in the class of Insects, to which they have indeed many strong points of resemblance. They deserve, however, a separate consideration, both on account of their general size and importance, and of some anatomical differences of structure, which will be pointed out. Among the most familiar examples are the lobster, crab, crawfish, the animal usually called the horseshoe, the barnacle, &c.

They have articulated limbs, antennæ, and jaws, similarly formed to those of insects, but they breathe by means of branchiæ or gills, and have a regular double circulation; in which particulars they differ from them. The blood which has passed through the gills, is collected into one large vessel, that distributes it to the whole body. On its return from the vessels of the body, it is collected into another vessel situated near the back, and performing in some measure the office of a ventricle, and is again sent to the gills. Their nervous system, and the degree of sensation they enjoy, are not essentially different from those of Insects.

They are covered by a pretty thick, firm shell, which envelops them completely. This serves for a shelter and protection to their soft parts, and also answers to them the same purpose, as an instrument of motion, that the internal system of bones does to the vertebral animals. As this shell is incapable of growth, it is occasionally changed, to make room for the constant increase of the animal in size. It is thrown off, and their bodies remain for a time entirely naked, and exposed in a soft and defenceless state. In this case the animal generally retires to some place of concealment and security, and remains till the shell is restored. This is done by the deposition of calcareous matter on the external membrane of the skin, which consequently becomes hard and firm, and finally takes the place of the old shell.

Fig. 44.



Crab.

The Crustacea have always as many as six claws, and frequently more. The two anterior ones are often prolonged, enlarged, and armed with teeth, so as in some measure to act in assisting the jaws. Their antennæ, like those of Insects, are probably intended to serve as very delicate organs of touch. They possess the sense of smelling, but naturalists have not been able to satisfy themselves in what organ it resides. The organ of hearing has been discovered. Their eyes are not placed loosely in a socket, but are fixed and immovable; and, to remedy the inconvenience which would result from this arrangement, they are, in some species, situated upon the end of a pedicle or stalk, which is capable of motion in every direction.

The stomach of some of the Crustacea presents a very singular and remarkable structure. It is exemplified particularly in the crab, lobster, crawfish, and others of the same kind. Near the lower end of the organ, where it begins to grow narrow, are situated a number of teeth, or substances of a bony nature resembling teeth, generally five in number. They are placed upon opposite sides, and, being moved by muscles belonging to them, thoroughly grind up the food passed between them, which then goes out at the orifice into the intestines.

These animals reside, for the most part, in the water. A few are found upon land. The former do not immediately die on being taken out of their natural element, but can live for some time in the air. They are generally carnivorous. Many of them furnish very delicious articles of food, although their flesh is sometimes heavy and difficult of digestion.

The term Vermes or Worms has been used with great vagueness in natural history, and employed to designate animals to which the name is not appropriate. It is now, however, more restricted in its application, and is made to include only a small class, which have some circumstances in common with each of the classes last described, but still not exactly resembling any. They are sometimes called, by way of distinction, *Worms with red blood*, as they are the only invertebral animals which have red blood; and sometimes *Annelida*, from the structure of their body, which is of a cylindrical, elongated shape, divided into a great number of rings.

Their nervous system resembles that of the Insects and Crustacea. Their organs of sense consist merely in some fleshy tentacula, which surround the mouth, and answer the purpose of feeling and touching. In some species, certain black points appear around the head, which have been supposed to be eyes, but this is doubtful. Their blood is nearly of the color of that of the vertebral animals, but not of so bright a red. It circulates in a double system of vessels, but there is no distinct, fleshy heart to give it motion. They breathe by means of branchiæ, which are sometimes within and sometimes without their bodies. They have no limbs, but on each of the rings of which their bodies are composed, are little bristly projections, which answer in some sort the purpose of feet. Their mouths are sometimes armed with jaws, and sometimes consist in a mere tube or sucker.

Their bodies are soft and compressible. Nearly all inhabit the water. Many of them bury themselves in the sand; others form themselves a sort of tube or habitation of sand, bits of dirt, gravel, or other materials; and others exude from their surfaces a calcareous matter, which produces a shell around them.

Among the animals belonging to this class are the earth-worm, the leech, and the hair-worm.

The appearance of Earth-worms is familiar to all. They attain sometimes to the length of a foot, and have as many as a hundred and twenty rings, each of which is furnished with the little bristles or spines above mentioned. They emit through certain pores a slimy fluid, which lubricates their bodies, and thus gives them an easier passage through the earth, which they traverse in every direction. They feed upon roots, woody fibres, and the remains of animal and vegetable matter. They swallow earth also in considerable quantities, but this is probably on account of the animal or vegetable matter, in a state of decomposition, which it may contain. When cut through the middle, each portion becomes a distinct individual. And in some worms nearly resembling the earth-worm, but residing in the water, the power of reproduction is nearly equal to that of the polypes.

The Leech has three jaws, or rather lancets, with which it pierces the skin of animals, in order to suck their blood. Its tail is furnished with a shallow cup or disk, by which it is able to fix itself firmly to different objects, while obtaining its nourishment in this manner; and by means of the same organ, it moves from place to place. There are several species of the leech, of which the medicinal is the most valuable, from the use made of it in local bloodletting. The horse-leech has the same power of drawing blood, but the wounds which it makes are sometimes followed by bad effects.

The body of the Gordius, or Hair-worm, is long, shaped like a thread or hair, nearly smooth, and round. It is a vulgar notion that the hair of the human head, or of a horse's tail, if thrown into the water, acquires life, and is converted into a worm. A species of the hair-worm, in Africa and the Indies, is extremely noxious. It is of a pale, yellowish color, and is frequently met with among the grass, especially when covered with dew. It often insinuates itself into the naked feet or limbs of children and unwary persons, where it produces an inflammation that is sometimes fatal. Great care and attention are required in extracting it; for if it be broken during the operation, the part which remains in the flesh continues alive, and is quite as troublesome as the whole.

CHAPTER VIII.

THIRD BRANCH OF THE ANIMAL KINGDOM.—MOLLUSCOUS ANIMALS.

UNDER this division are included a great variety of animals, of most of which the structure, residence, and habits are less perfectly known than those of the preceding classes. In their internal structure and organization, they are, for the most part, superior to the members of the division of Articulata, but as to intelligence and instinct, they are upon the whole inferior. Among them are the cuttle-fish, squid, oyster, clam, snail, and nearly all those commonly known as the testacea or shell-fish.

The Mollusca are destitute of bones and of articulated limbs. Their bodies are generally of a soft texture, and in many, at first sight, appear to be little else than a simple mucous mass, without parts, and almost without organization. Their muscles are fixed into the skin, which is naked, very sensible, and constantly moistened by a fluid furnished by its pores. The contractions of these muscles produce various motions of their whole bodies, often obscure and indistinct, by means of which, nevertheless, they are enabled to swim and crawl, or even seize those objects which are adapted to their nourishment. But as no part is supported by any solid foundation, like the bones of vertebral animals, their motions are for the most part slow, awkward, and limited.

Their bodies are generally covered by a fold or reflection of the skin, which envelops them completely, and is called their mantle. (Fig. 8, Oyster.) In some species, the two folds of the mantle are united at their edges, so as to form a complete bag, in which the body of the animal is contained, opening only at one end by a sort of canal or snout: in some, it extends in two opposite directions, so as to answer the purpose of fins or oars. Sometimes there is only this simple membranous covering; but more frequently there is a hard external shell, which serves as a retreat into which the animal may withdraw itself, and which it can carry about upon its back in all its changes of place. These shells differ a good deal in shape, color, and texture, in different species; and among them are found some, whose form, polish, and splendid tints place them among the most beautiful objects in nature.

The Mollusca have no brain nor spinal nerve. Their nervous system consists merely of a number of masses, distributed in different parts of their bodies, from which are sent out a great many small branches, that mutually unite with each other. The principal of these, which is sometimes called the brain, is situated around the œsophagus, and envelops it like a collar. In a few species it is contained in a cartilaginous case. Their respiration is not uniform. It is generally carried on by organs resembling the gills of fishes, which are acted upon either by fresh or salt water; but, in some cases, air is respired directly from the atmosphere. The circulation is double; that is to say, there is a passage of the blood through the respiratory organs, distinct from that through the rest of the body. This circulation is carried on by either one or more hearts. When there is only one, it is situated so as to receive the blood from the gills, and circulate it through the body. When there are two, the second is situated so as to circulate through the gills the blood coming from the body. In some species, there are three hearts; and in this case, as there are two sets of gills, a distinct heart is devoted to each. The blood in the Mollusca is thin, of a bluish white, and of the temperature of the medium in which they live.

The organs of digestion vary very much. Sometimes there are organs for mastication, and sometimes not. Some species have only a single stomach, and others have several; the structure of this organ, in some species, very much resembling that of the gizzard of birds. In some species there are four stomachs, which bear a great analogy to those of the ruminating animals, and have been supposed to answer a similar purpose. In the intestines there is as great a variety.

This branch is divided into several classes, according to the general form and structure of the species composing it. A few of the most important particulars that distinguish some of them will be pointed out.

In the first class, containing the cuttle-fish, squid, and nautilus, the body consists of a sack formed by the mantle, enveloping all the parts except the head, which projects from it, and is provided with a number of fleshy arms or feet, tapering towards their end, frequently of great length and of great power. These arms are capable of being moved in every direction, and are furnished with a large number of suckers in the form of cups, by which the animal can attach itself very closely to whatever object it embraces. They serve for swimming, for creeping, and for seizing prey. In all its motions, the head goes last, so that the animal in a manner pushes itself backward in whatever direction it wishes to move. Between the arms is placed the mouth, which is furnished with two strong jaws of a horny texture, and in shape resembling the beak of a parrot.

Some of these animals have the power of ejecting a peculiar liquid of a black color, when in any danger, for the purpose of discoloring the water of the sea around them, and thus concealing themselves from their enemies. The cavity containing this liquid is situated in the abdomen, and is sometimes found in the very substance of the liver. It has been supposed, that the celebrated paint called Indian ink, is made by the Chinese from the inky fluid of some animal of this kind.

Their eyes are large and perfect. They have an ear; but no organ for smelling has been discovered, although they probably possess that sense. Their nature is fierce and cruel. They are very voracious, and devour great numbers of fishes and other aquatic animals.

Some of these animals grow occasionally to a great size. This is more particularly the case with the eight-armed cuttle-fish. In the Indian seas, it is popularly supposed to attain to such a magnitude, that its arms are nine fathoms in length, and the other parts of its body large in proportion. The natives hold it in great dread, fearing that it will lay hold of their boats, and drag them under water. They keep themselves provided with hatchets, to cut off its arms, should any danger arise from this cause.*

In another class, which includes the snail and the greater part of cockles, the foot, or instrument of motion, is placed under the belly of the animal, and consists of a fleshy plate or disk, protected underneath by a layer of a horny or calcareous substance, which, when the animal retreats into its shell, serves to close up its opening. Their mantle is fixed upon the back, and covers more or less of the body, the head also being partly enveloped by it. The mouth has generally a few tentacula or feelers beneath it, but they are sometimes wanting. The eyes are very small, sometimes fixed to the head, and sometimes situated upon the end of the tentacula; but they are also sometimes wanting. These animals are almost always furnished with shells, which serve them as a residence.

The Mollusca of another class, including the oyster, the clam, the quahaug, the mussels, and, in short, all the bivalve shell-fish, have no apparent head, but only a mouth surrounded by four tentacula, and situated beneath the folds of their mantle. The mantle is generally composed of two folds, which inclose the body between them, as a book is contained within its covers. Sometimes the edges of the two folds are united together, and form a complete sack. In the common clam, this sack terminates in a long, double, fleshy tube, which is usually called the head of

* A curious but perhaps apocryphal account of an enormous animal, which was probably of this kind, is found in the works of Pliny, who cites it from a writer named Trebius. This animal made its appearance on the coast of Carteia, and was in the habit, during the night, of robbing of their contents certain reservoirs of salt fish, which were situated near the seaside. Its depredations were not prevented by a row of stakes which were so planted as to intercept communication with the sea. It was found that the animal made use of a tree, which grew near the stakes, to assist it in climbing over them, and it was finally attacked, while in the reservoir, by a number of dogs and men. It made a powerful resistance, and lashed the dogs smartly with its arms, but was finally killed. Its body was as big as a hogshead; its arms, called its beards, were as big as a man could clasp, and thirty feet long; and its cups or suckers held four gallons each. It weighed 700 pounds. The popular belief in an animal called the Kraken may have been derived from the appearance of very large specimens of creatures of this description.

the animal, but in fact serves a totally different purpose; one of the tubes being for the entrance of the water which supplies the gills in respiration, and the other serving as the termination of the intestinal canal. The true mouth of the animal is situated at that part of the body which corresponds to the other extremity of the shell.

The Giant Clam is the largest of the testaceous Mollusca. Its shell is more than three feet long, and its body forms a meal for a number of persons. It is found in the Indian seas, and in different parts of the Pacific Ocean.

Many of the animals of this kind are furnished with an organ denominated their foot, consisting of a fleshy mass attached to their body, whose motions are produced like those of the tongue of quadrupeds. This foot often gives rise to a number of filaments or threads, by which the animal is capable of attaching itself to rocks or other marine substances; thus, as it were, being moored or anchored, and secured from the influence of the waves. The two valves of their shell are held together by strong muscles which pass from one to the other; and when these are relaxed, the shells open mechanically, by means of an elastic substance placed in the hinge of the joint which connects them.

There are several other classes of the Mollusca, but the characteristics by which they are distinguished are too obscure or minute to be here described.

CHAPTER IX.

FOURTH BRANCH OF THE ANIMAL KINGDOM.—RADIATED ANIMALS.

UNDER this are included an immense number of individuals whose structure and habits are but imperfectly known, and which have but few apparent points of resemblance or connection, except a radiated arrangement of their organs around a common centre, which has been mentioned as their characteristic plan of structure. These animals were formerly included under the general denomination of Zoöphytes, from their supposed approximation to the vegetable kingdom in their nature and organization. In general they have no nervous system, no complete vascular circulation, no distinct apparatus for respiration, and no sense but that of feeling, and perhaps that of tasting. This is not true, however, without exception; for in some instances, traces of a nervous system, of a circulation, and of respiratory organs, may be detected, as is particularly the case in the Echinodermata, the first class of Radiata. These are covered with a well-organized skin, and often with a sort of shell with points or spines. They have an internal cavity, with several distinct intestines, and vessels which maintain an imperfect circulation. There are also distinct organs for respiration, and many filaments that probably perform imperfectly the functions of a nervous system. To this class belong the sea-urchin, the common starfish, and the sea-egg. They are the most perfect of Radiata in their structure, and are endowed with a curious set of organs for the purpose of motion. Their shells are pierced with a large number of holes, regularly arranged, through which project the feet, or rather the instruments answering the purpose of feet. These are little hollow cylinders, composed of a membranous substance, and ending in a kind of knob, which is also hollow. They are filled with a liquid, which is furnished to them by reservoirs situated within the body. The animal at will can either lengthen these cylinders and distend their extremities by forcing this liquid into them, or exhaust it, and thus shorten and contract them. When it is exhausted, the knob or disk is drawn into a cup-like form, and thus may be firmly fixed to whatever object it is applied, like a cupping-glass; and when the liquid is again thrown into it, it is again loosened. By this arrangement, which enables it to fix and loosen, and at the same time to lengthen and shorten these organs, it is enabled to move itself from place to place. Some of the animals of this class are composed of several branches united together in one common centre, like the spokes of a wheel; and hence they are called starfish, or more commonly five-fingers. Their mouth is in the centre, where the several branches meet. Others are globular, and others oblong, as in the sea-urchins and sea-eggs.

The Sea-nettles, or Sea-anemones, (Fig. 9,) are less perfect. Their bodies are circular, and in their centre is the mouth, which leads to several rude and imperfect cavities in the substance of the animal, answering the purposes of stomach and intestines. They are generally found attached by their base to some rock or marine substance; but this attachment is voluntary, for they can at will disengage themselves. Generally, however, they perform no other motion than that of opening and closing their mouths, and extending the tentacula with which they are surrounded. With these they grasp animals coming within their reach, such as small fish, mollusca, and worms. These they swallow, and after having digested their flesh, throw out their bones, shells, and other refuse matter by the same opening, which is their only one.

The Medusæ do not differ much from these, except that they are apparently of a gelatinous, slimy consistence, and are never found fixed by their base. They are common, and are often seen in immense shoals. One species of them is popularly known by the name of sunfish.

The Polypes have a hollow, cylindrical, or conical body, with one extremity open, which serves for the mouth, and is surrounded by a number of tentacula. The simple cavity thus formed constitutes their only organ, and performs all the functions of which they are capable. They seize their prey and convey it to their mouths with the tentacula, and, as their bodies are gelatinous and semi-transparent, the operation of digestion may be seen going on within. The immense beds of coral, and the different kinds of sponge, are the product of myriads of these little animals and are in some sense to be regarded as their habitations.

The Animalcules are animals still more minute, and are few of them discernible except by the assistance of the microscope. Thousands of them are in this way brought to our view, of various shapes, sizes, and appearances. Most of them present merely a gelatinous mass, capable of an imperfect sort of motion. Some, however, present appearances of a structure which might give them a claim to a higher rank in the scale of beings, did not their minuteness prevent a proper examination. These animals are very often found in animal and vegetable fluids and infusions, and hence have received the name of Infusoria.

The following extract from a late writer exhibits in a striking manner the variety and characteristics of these animals, and displays to us a world of life, visible only through the microscope, scarcely less various and wonderful than that of which we are able to take cognizance by our unassisted senses. "From some water containing aquatic plants, I select a small twig, to which are attached a few delicate flakes, apparently of slime or jelly. This twig, with a drop or two of the water, we put between two thin plates of glass, and place under the field of view of a microscope, having lenses that magnify the image of an object two hundred times in linear dimensions. Upon looking through the instrument, we find the fluid swarming with animals of various shapes and magnitudes. Some are darting through the water with great rapidity, while others are pursuing and devouring creatures more infinitesimal than themselves. Many are attached to the twig by long, delicate threads; several have their bodies inclosed in a transparent tube, from one end of which the animal partly protrudes and then recedes; whiie numbers are covered by an elegant shell or case. The minutest kinds, denominated *monads*, many of which are so small that millions might be contained in a single drop of water, appear like mere animated globules, free, single, and of various colors, sporting about in every direction. Numerous species resemble pearly or opaline cups or vases, fringed round the margin with delicate fibres, that are in constant oscillation. Some of these are attached by spiral tendrils; others are united by a slender stem to one common trunk, appearing like a bunch of harebells; others are of a globular form, and grouped together in a definite pattern on a tabular or spherical membranous case for a certain period of their existence, and ultimately become detached and locomotive; while many are permanently clustered together, and die if separated from the parent mass. No organs of progressive motion similar to those of beasts, birds, or fishes, are observable in these beings; yet they traverse the water with rapidity, without the aid of limbs or fins; and though many species are destitute of eyes, yet all possess an accurate perception of the presence of other bodies, and pursue and capture their prey with unerring purpose."

Among the most singular and important of the facts connected with this minute race of animals, is the existence in certain species of a case, shell, or shield, composed of lime, flint, or iron. These are indestructible, and remain after the animal has perished, forming immense beds, in the same way in which are sometimes found large collections of the remains of shell-fish. "From the inconceivable number of these shell-animalcules, which swarm in every body of water, whether fresh or salt, and the immense rapidity with which the species increase, extensive deposits or strata of their cases are constantly forming at the bottom of lakes, rivers, and seas. Hence have originated the layers of white calcareous earth common in peat-bogs and morasses; the tripoli or polishing slate of Bilin consisting wholly of the siliceous cases of animalcules, and the bog iron composed of ferruginous shields of other forms." The wonderful minuteness of these animals is shown by the fact that a cubic inch of the stone contains forty-one billions (41,000,000,000) of distinct organisms. The minuteness of the animalcules composing a kind of ochre, is stated to be even more extraordinary—a cubic inch containing no less than a trillion of them (1,000,000,000,000.)

Their prolific nature is no less remarkable than their size. Such is the rapidity with which they multiply that in one species a single individual may in four weeks have descendants to the amount of 268,435,456; and, according to Ehrenberg, some species are so fertile that 140,000,000 may proceed in four days from a single germ.

This completes a view of the whole animal kingdom, beginning with man, the most perfect member of it, and descending to those obscure and minute creatures which are only visible with the assistance of the microscope. It will be observed that one common plan pervades the whole; that the same general objects are had in view in the structure of all, and that there is a general analogy in the methods employed for effecting these objects, although there is a great variety in the details; that there is a grand simplicity in the design, though a great diversity in the means. In short, not only in the structure of each individual animal, but in the wonderful manner in which the structure is varied to correspond to the nature, habits, and wants of the different classes, we may perceive the power, the wisdom, and the goodness of that great Creator, who has devised and formed, and who continues to sustain, the myriads of animated beings with which the earth is filled.

THE PHILOSOPHY

OF

NATURAL HISTORY.

CHAPTER I. (W.)*

OF THE FOOD, DIGESTION, AND BLOOD OF ANIMALS.

A GENERAL view of the several functions that subserve the purposes of animal life has already been given in the Introduction; but there are many other circumstances relating to them which still remain to be considered.

The form of the face and head, the general structure and proportions of the body and limbs, the means of attack and defence, the strength, agility, and speed of an animal, all correspond to the organs of digestion, and bear a definite relation to them, and to the kind of food.

Man cannot seize his food with his mouth, for his lips and teeth are upon a plane with the general surface of his face; but he has hands by which he conveys it there. In other animals, just in proportion as the hands or fore feet become less adapted to this purpose, the mouth, face, and teeth become projecting, so as to make up for the deficiency. Thus the hands of the monkey are less perfect than ours, but his face is more protuberant. The Carnivora have jaws of more power, and hands again of less, whilst in the hoofed animals — as the horse, and ox — the jaws

* In the subsequent parts of this work, the chapters which are taken chiefly from the original publication of Smellie are denoted by S., and in these the passages substituted or added in the present edition are distinguished by a single inverted comma. The chapters prepared chiefly by the Editor are denoted by W., and the passages retained from the original are distinguished in the same way.

become very protuberant, and the fore feet are merely adapted for motion. This gradation in structure is also connected with the kind of food. Where an animal, as a hoofed quadruped, feeds upon substances firmly fixed to the earth, the mouth and teeth are sufficient. Where the food is not fixed, as flesh or fruit, something more is required. Hence animals living upon flesh, use their fore legs to hold down their prey while they tear it with their teeth; those living upon small fruits hold them between their fore feet, like the squirrel; whilst man and the monkeys, whose food is more various, have hands by which they can handle and prepare it.

Man is evidently capable of living, and does live, upon a great variety of food. But the question has been often discussed, whether his natural food be animal or vegetable? Is he, like most other animals, fitted by his nature to subsist upon a particular kind, or was he intended for that variety of diet, to which he has recourse? In his anatomical structure he is certainly most nearly allied to those species, such as the monkeys and their allied tribes, which in a state of nature live exclusively on fruits and vegetables. But experience shows that he is able to live, and enjoy at least equal health and strength, upon substances from the animal kingdom also. Some nations live exclusively on the one, some on the other; whilst the majority of mankind are addicted to the indiscriminate use of both. The tribes of Esquimaux, who inhabit the northern extremities of the earth, subsist entirely upon the flesh of whales, seals, walruses, bears, and fishes, never, except by accident, having the opportunity of tasting vegetable food. The Indians and Spaniards inhabiting some of the extensive plains of South America, frequented by immense droves of cattle, live almost exclusively upon beef. The Arabian supports himself on dried horseflesh, dates, and the milk and flesh of the camel; the millions of some of the regions of the East consume little else than rice; and the inhabitants of many portions of the tropical regions of the earth, subsist chiefly upon fruits and vegetables. Among the civilized nations of Europe and America, the tables of the better classes are spread with an immense variety from both kingdoms of Nature, whilst many of the poorer are limited to bread and vegetables.

Under all these different circumstances of diet, the average amount of health and strength does not seem, to common observation, to differ materially, so far as it is dependent on the kind of the food. Other circumstances appear to have more influence; such as the general mode of life, the occupation, the clothing, the habitations, and the quality and supply of air. It is probably true that if man have a sufficient quantity of aliment, and if his habits of life are well ordered in other respects, he may enjoy health, strength, and long life, upon all the kinds of food which have been mentioned. It is also true, however, that those tribes or classes of men whose situation enables them to gratify the appetite by a considerable variety, are more likely to attain to a high state of physical development, than those that are rigidly confined to a few articles.

The application of heat in the preparation of food undoubtedly contributes to the capacity for enduring this variety. Heat changes its texture and qualities; skilfully applied, it reduces very heterogeneous substances to a near approximation in their digestibility. Domestic animals whose food is cooked, resemble man in this respect. The dog and cat will subsist very well, and even exclusively, upon vegetable food, whilst, to some extent, though far less, some vegetable-eating animals will take animal food.

In fact there is not so great a difference between the products of the two kingdoms of Nature, used as food, as their sensible qualities would lead us to suppose. They consist essentially of the same principles. The vegetable world is the great laboratory in which food is prepared for the animal; and after its products have entered the bodies of animals, they are not greatly changed in their composition and essential qualities as articles for nutrition, though they are much altered from the texture and form in which they were swallowed.

The question then of the natural food of man is hardly capable of solution. It is as difficult to determine as that which relates to a supposed state of nature in other respects. Probably there is, in the proper sense of the word, no absolute or uniform state of nature. Calculated for an extensive distribution over the surface of the earth, man has been endowed with a power of accommodating himself to great differences in country, climate, and food. He was probably not intended for any one residence more than another. He was intended for just what his instincts and propensities lead him to. As much for a hot climate as a temperate one, and as much for a cold one as either.

But though thus capable of living upon this variety of food, there is an almost necessary connection between certain conditions of life and its kind and quantity. In cold climates, not only a larger quantity is required, and of animal origin, but also that containing a great proportion of fatty matter. This is supposed to be rendered necessary in order to maintain the animal heat by its consumption. In hot climates, on the contrary, where this is hardly at all required, the quantity of food may be less, and especially of that containing fat. So, too, great bodily labor is supposed to be best maintained on a large proportion of animal food, but a sedentary and indolent life to require chiefly that of vegetable origin. There is probably a general truth in these opinions, but the deviations are so many as to render them liable to much modification.

Thus in the interior of Africa, in a hot climate, we are informed by travellers that the capacity for taking and digesting food is great. Dr. Oudney says of the Tuaricks, "We were told of two men who consumed three sheep at a meal; another who eat a kail of bruised dates, with a corresponding quantity of milk; another who eat about a hundred loaves of the size of an English penny loaf."

Still there is no reasonable doubt that in cold climates the demand for fatty animal food is more uniform, and the capacity of subsisting without it is less, than in warm. Indeed the instinctive avidity for it is sometimes almost startling. Captain Cochrane relates, that in Siberia he saw a child scrape up candle grease from the floor to eat, as a child with us might scrape up molasses. He gave it three tallow candles, several pounds of frozen sour butter, and a large piece of yellow soap. All were eaten with avidity. The Yakeite or Tongousi will eat anything, however putrid or repulsive. He has seen one of them eat forty pounds of meat in a day, and three of them eat a reindeer at a meal. Captain Parry, in his Voyage to the North Pole, states the following experiment on a young Esquimaux lad, scarcely full grown, not as anything uncommon, but simply as an illustration of the demand for food, and the capacity for digesting it, among persons enduring the cold of a northern climate. The following amount of food and drink was dealt out, and consumed by him in the course of twenty hours, without any apparent inconvenience:

	lbs.	oz.
Flesh of seahorse, frozen	4	4
" " " boiled	4	4
Bread and bread-dust	1	12
Solids	10	4

Rich gravy soup	$1\frac{1}{4}$ pints.
Raw spirits	3 wineglassfuls.
Strong grog	1 tumblerful.
Water at 32°	1 gallon, 1 pint.
Liquids, about	11 pints.

The whole would amount to about twenty-one pounds of solids and liquids, or about one sixth of the weight of his whole body. This quantity, however, enormous as it is, is far exceeded by that devoured by some birds. Professor Treadwell, of Cambridge, noted carefully the amount of food consumed by a young robin during its period of growth, and found that he eat greedily more than his own weight of solid food daily, consisting chiefly of earth-worms and butchers' meat. At one period in the course of the experiment the daily weight of his food was thirty-four dwt., while his own was twenty-four dwt. He therefore consumed about forty-one per cent. more than his own weight.

It is found that those animals whose mode of life requires great, violent, and sudden exertions of strength, are carnivorous; whilst rapid and persevering motion is chiefly observed in the herbivorous. Of the former, we have examples in the lion and tiger; of the latter, in the horse and reindeer. But it is very doubtful whether any just argument can be derived from this analogy, in favor of any particular views concerning the food of man, or its adaptation to particular kinds of labor.

There is sufficient reason to believe, as the result of all that is known on this subject, that the best food for man is a combination of animal and vegetable, differing in the proportion they bear to each other according to climate and occupation; that he is better nourished and developed if he has a considerable variety of diet; and that the digestibility of most substances is improved by being cooked. But even this last is not universally true, since among savage nations meat is often eaten raw and is thus preferred. A late traveller in Abyssinia (Mr. Parkyns) states this to be the case in that country, and that the inhabitants regard meat as more tender and relishing if cut directly from the animal when life is barely extinct; that not long after death the fibre becomes tough and less delicious. Accordingly at the feasts of the higher classes a cow is slaughtered on the spot, and the warm flesh served up to the company, just as it is cut in strips from the warm and still quivering carcass. In Dr. Kane's narrative of his late expedition to the polar seas, many facts are stated which indicate not only the capacity of man for thriving on raw flesh, but also its superior adaptation, under certain circumstances, to his support under great labor, hardship, and exposure to cold, and also to the prevention and removal of disease.

In the selection of particular articles among different vegetable and animal substances, man is determined very much by caprice, prejudice, and accident, and sometimes by superstition. Locusts are esteemed excellent food by some nations, and are eaten in large quantities, roasted, boiled, and dried. A European or American would almost shudder at the idea of feeding upon the common grasshopper, which is probably as suitable food. The Australian devours with avidity grubs and worms; the African feeds upon ants; we regard oysters and clams as excellent articles of diet, whilst snails, leeches, and worms are rejected with loathing. There is good reason to believe that the flesh of many animals which we should shrink from with disgust, is in reality perfectly well adapted to the wants and probably would be to the taste of man, as the horse, dog, cat, rat, and mouse. Indeed they are all eaten by some nations, and even by Europeans when pressed by hunger.

A strange kind of food is resorted to in times of scarcity by the savage nations of different parts of the world, namely, earth, either by itself, or mixed with other articles. The kind usually resorted to is an unctuous, almost tasteless clay. On the banks of the Orinoco, this is kneaded into cakes, baked before a slow fire, and preserved for use. By habit it becomes agreeable to the palate, and is eaten even when not rendered necessary by the want of other suitable food. The slaves in the West Indies have been specially addicted to dirt-eating, and although from its supposed injurious effect it was forbidden by their owners, they were with difficulty restrained from the practice. This practice has been chiefly observed in the torrid regions. It is not, however, confined to them, but prevails also in China, Finland, and Lapland. Part of the influence of this kind of food is probably due to the feeling of fulness which it gives to the digestive organs, and which is necessary to the perfect satisfaction of the appetite; but it has also been supposed that there may be mixed with the earth large quantities of animalcules which give to it a nutritious quality.

In the interior of South Africa, according to Dr. Livingstone, there is a tree, called mopané, on whose "leaves the small larvæ of a winged insect appear, covered over with a sweet, gummy substance. The people collect this in great quantities, and use it as food; and the copavè — large caterpillars three inches long, which feed on the leaves, and are seen strung together — share the same fate."

A too exclusive confinement to a particular kind of diet, especially to a very limited number of articles, with very little variety of kind, is apt to be productive of disease, or at least to interfere with the proper growth and development of the body. In some public institutions, under such a diet, dysentery of a bad character has prevailed. The scurvy is occasioned by a too exclusive use of salted provisions, with a deficiency of fruit and vegetables. Captain Franklin, on his land journey to the arctic regions, found that his men contracted dysentery from an exclusive diet of dried flesh and fish; that they were enfeebled by it, particularly by the latter. Those Eastern nations that live chiefly on rice, are weak and inefficient, incapable of great exertion, and liable to many diseases, probably to be attributed to this kind of food. The chiefs of many of the South Sea Islands, who are well fed, are large and strong; whilst the lower classes, on the contrary, whose food is poor, and who seldom taste flesh, are small and weak. The same general difference may be observed among the nations of Europe, when the condition of the higher classes is compared with that of the lower. Loss of health, disease, and death have been largely produced among soldiers of the English army by an exclusive diet of even so nourishing articles as boiled beef, bread, and potatoes.

It is partly by his power of thus accommodating himself to various kinds of food, that man is capable of residing in all the different regions of the earth. It is partly also owing to his skill and address in cultivating the earth, and in procuring various forms of animal food by hunting, fishing, and domestication, and to the sagacity which enables him to avail himself of the protection afforded by habitations, clothing, and the use of fire. It is the want of these which confines other animals for the most part within certain limits. The frugivorous animals of the torrid zone would perish in the frigid, from cold and the want of fruits and vegetables. The polar bear, the walrus, and other inhabitants of the arctic regions, would probably meet with the same fate in those around the equator. A few animals, especially the dog, have been found the usual attendants upon man in his distribution over the earth; but even these appear to owe their capacity for enduring these migrations to the aid of their common master, and to the extension to them of the same expedients which he has found necessary for himself.

This relation of animals to each other, and of the animal kingdom to the vegetable, is one of the causes which regulate the distribution of life over the earth. Some species are confined to a very narrow range, others extend over a wide. None, perhaps, are dispersed over a whole continent, and only a few are common to the two hemispheres. This is in some part determined by their several demands for food. Every vegetable substance is fed upon by animals, or in its decay affords nourishment to other vegetables. Every animal is liable to become in its turn the prey of other animals. If not devoured alive by its enemies, it furnishes a feast to worms and insects after its death, or, by enriching the soil where it falls, aids in the growth of plants. Universal destruction and universal renewal is thus the law of all life, and by means of it life is made to pervade every spot and cranny in the earth.

The suffering which appears to be the necessary accompaniment of this relation of animals to each other, is alleviated in various ways. Whilst the assailant, on the one hand, is furnished with means of seizure and attack, his prey, on the other, has those which give him a reasonable chance of escape. The lion has strength to overcome the horse, but the horse, gifted with a most delicate ear and superior fleetness, perceives his approach, and leaves the danger behind. The hawk discerns the lizard or mole in the grass from an immense height in the air, and pounces down upon him; the little animal shrinks beneath a stone or into his burrow, and the powerful marauder is defeated. The owl sees clearly in the dusk, and glides softly through the air on muffled wings, to seek a prey whose nicety of hearing is proportioned to the feebleness of the sound which warns him of the danger. The duck, when the falcon descends upon him from the clouds, dives beneath the water. The flying-fish, pursued by the voracious shark in his own element, takes refuge in the air. There is no end of these provisions by which Nature seems, as it were, to defeat her own objects. But it is not so; they are intentionally incomplete. No one animal has an unmixed advantage over any other. There is always some compensation; always some disadvantage to qualify it. So, too, there is no disadvantage, without a corresponding compensation. The advantage which the lion has over other animals in certain particulars, has an offset in his want of a delicate smell. The disadvantage which the horse and zebra labor under as his neighbors, is compensated by their acuteness of ear, and swiftness of foot; that of the buffalo, by the strength of his neck and horns; that of the elephant, by his tusks and trunk. It is so everywhere else. No animal is given up to inevitable destruction; there is always a hope of escape, and the exertion necessary to improve its chance lessens the pain of fear, and takes away that apprehension of death in which its terrors chiefly consist.

A remarkable statement of Dr. Livingstone illustrates in a striking manner another provision intended for the alleviation of the horrors which we may suppose to attend the seizure and destruction of animals as prey. "Starting, and looking half round, I saw a lion just in the act of springing upon me. I was upon a little height. He caught my shoulder as he sprang, and we came to the ground both together. Growling horribly close to my ear, he shook me as a terrier does a rat. The shock produced a stupor similar to that which seems to be felt by a mouse after the first shake of the cat. It caused a sort of dreaminess, in which there was no sense of pain or feeling of terror, though quite conscious of all that was happening. It was what patients partially under the influence of chloroform describe, who see all the operation, but feel not the knife. This singular condition was not the result of any mental process. The shake annihilated fear, and allowed no horror in looking round at the beast. This peculiar state is probably produced in all animals killed by the Carnivora; and if so, is a merciful provision by our benevolent Creator for lessening the pain of death."

Man is directed, in the selection of his food, partly by accident, and partly by experience and the aid of his senses. That which is agreeable to the taste is usually healthful to the stomach; and by a constant observation of the effects produced by different kinds of food, he has gradually learned certain general rules for distinguishing nutritious and salutary articles from others. Still he has no guide so unerring as the instinct of animals, and the young of our own species will often partake of poisonous plants, a mistake seldom made by those of other animals. For the most part, the Mammalia depend upon the smell as their guide, though sometimes when at fault they subject the doubtful article to the taste. Birds depend more upon sight, but partly also on the smell and taste, or upon them combined, as we see in the domestic fowl.

There is often something capricious and unaccountable in the selection made by animals. Those apparently nearly alike in structure and habits, do not uniformly agree in the food they choose. The ass will eat food which the horse rejects; there are some herbs which the goat, cow, and sheep, nearly allied in structure and habits, will not partake in common. This is partly a matter of taste. We often observe, even in those of the same species, that some individuals partake of that which others reject. Necessity, too, will often oblige them to have recourse to an article which is not only at first distasteful, but repugnant to their instincts. Yet in time they accommodate themselves to it, so as not only to be well nourished, but absolutely to prefer it. Thus in some cold countries, horses are fed upon dried fish. In some fishing towns, cows are fed upon fresh fish, or the parts of them which are usually thrown away. Monkeys become very fond of meat. Rabbits and hogs frequently devour their young. Dogs are easily taught to live upon bread, and even raw fruit and vegetables; even the household cat, a more exclusively carnivorous animal, may be reared in the same way, and flourish wholly upon vegetable food.

But this power of accommodation has its limits, and there are many articles eaten with impunity by some animals, which are absolutely poisonous to others. The term poison is relative. The healthful food of one, is fatal to another. We are told by Dr. Livingstone that the milky juice of the euphorbia, which is harmless to oxen, is fatal to the zebra, and that the hornbill feeds with impunity on the deadly fruit of the strychnos. There is no vegetable substance deadly to man, which is not the food of some other animal. Even some mineral substances which are destructive to the life of one species are swallowed with impunity by some other. Thus corrosive sublimate is taken by the eagle with little more effect than so much sugar; whilst common salt, in any considerable quantity, kills the common fowl. Among individuals of our own species, it is not uncommon to observe analogous varieties in the taste, and capacity for taking different kinds of food. Some persons have a strong repugnance to particular articles. In some cases this is simply a matter of taste; in others the article is absolutely injurious. This happens even with regard to the most healthful substances, such as milk, butter, cheese, pork, or mutton. It is more frequent as to certain less common ones, as lobsters, clams, mussels, oysters, mackerel, and similar fish. To this peculiarity of constitution is given the name of idiosyncrasy. It relates to other substances beside food, and even to some which are not introduced into the stomach.

The odor of roses produces in certain persons a rash upon the skin; in others a cough, and difficulty of breathing, with other symptoms like those of a severe cold. A similar condition is produced in others by the emanations from other flowers and from hay. The powder of ipecacuanha will in some produce the same affection in a very severe degree, when breathed into the lungs. And as an example of the different modes in which this peculiarity exhibits itself, we are informed by Tennent that the bite of the ttetse fly of Africa, which is deadly to the horse, ox, and dog, is harmless to man and wild animals.

A singular example of the nice adaptation of the kind of food, to a particular species, and of the deleterious effect of that which would seem very nearly resembling it, is given by the celebrated Réaumur. He remarks that such insects as feed upon dead carcasses, and whose fecundity is great, never attack living animals. 'The flesh-fly deposits her eggs in the bodies of dead animals, where her progeny receive that nourishment which is best suited to their constitution. But this fly never attempts to lay her eggs in the flesh of sound and living animals. If Nature had determined her to observe the opposite conduct, men, quadrupeds, and birds would have been dreadfully afflicted by the ravages of this single insect. Lest it might be imagined that the flesh-fly selected dead, instead of live animals, because, in depositing her eggs, she was unable to pierce the skin of the latter, M. de Réaumur made the following experiment, which removed every doubt that might arise on the subject. He carefully pulled off all the feathers from the thigh of a young pigeon, and applied to it a thin slice of beef, in which there were hundreds of maggots. The portion of beef was not sufficient to maintain them above a few hours. He fixed it to the thigh by a bit of gauze; and he prevented the pigeon from moving, by tying its wings and legs. The maggots soon showed that their present situation was disagreeable to them. Most of them retired from under the slice of beef; and the few that remained perished in a short time. Upon the same pigeon M. de Réaumur performed another experiment. He took off the skin from its thigh, laid bare the flesh, and applied immediately another slice of beef, full of maggots. The animals discovered evident marks of uneasiness; and all of them that remained on the flesh of the pigeon were deprived of life, as in the former experiment, in less than an hour. Hence the worms sometimes found in ulcerous sores must belong to a different species from those upon which the above experiments were made.' The heat of the living body, in these cases, has been supposed to be the occasion of death. It is more probable that it is to be attributed to the want of their accustomed food, or to the directly injurious effect of that with which they were placed in contact.

Some of the details connected with the digestion of food, especially those which relate to the grinding and dissolving of it in the stomach, in order to its conversion into chyle, are worthy of further attention. Some physiologists have attempted to explain the process of digestion solely by reference to mechanical force, and others by attributing it to chemical action alone. Probably it is due to a combination of the two. In some animals more mechanical force is required, whilst in some the solvent power of chemical agents is put chiefly in requisition. A great variety of experiments have been made upon man and other animals, a few of the most remarkable of which are subjoined.

Spallanzani, who made a great number of original observations and experiments upon digestion, directed his attention to this function, as taking place in animals with three different kinds of stomach. 1. Those with strong muscular stomachs or gizzards, as hens, turkeys, ducks, geese, and pigeons. 2. Those with stomachs of an intermediate structure, as crows, herons, &c. 3. Those with membranous stomachs, as man, the Mammalia, many Birds, particularly the accipitrine, Reptiles, and Fishes.

1. In his experiments upon birds with strong gizzards, Spallanzani forced down their throats small glass and metal balls and tubes, filled with grain, and perforated with many holes, in order to give free admission to the gastric juice. The grain was in its entire state. At the end of different periods, varying from twenty-four to forty-eight hours, the animals were killed and the balls examined. No change had taken place in the grain. There was no diminution of size, and no marks of dissolution were to be seen. In all his experiments, which were numerous,

the event was uniformly the same. Suspecting that, although the gastric juice might be unable to dissolve grains in their entire state, it might act as a solvent upon them when sufficiently masticated or bruised, he repeated his experiments, filling his balls with bruised grain. In all his numerous trials upon this plan, he invariably found that the grain was more or less dissolved, in proportion to the time the balls were allowed to remain in the stomach.

When tin tubes full of grain were thrust into the stomachs of turkeys, and allowed to continue there a considerable time, they were found to be broken, crushed, and distorted in such a manner as to evince the existence of a most powerful comminuting force. "Having found," says Spallanzani, "that the tin tubes which I used for common fowls were incapable of resisting the stomach of turkeys, and not happening at that time to be provided with any tin-plate of greater thickness, I tried to strengthen them, by soldering to the ends two circular plates of the same metal, perforated only with a few holes for the admission of the gastric fluid. But this contrivance was ineffectual; for after the tubes had been twenty-four hours in the stomach of a turkey, the circular plates were driven in, and some of the tubes were broken, some compressed, and some distorted, in the most irregular manner."

These smooth substances, although violently acted upon, could not injure the stomach, and Spallanzani was therefore induced to try the effect of sharp bodies. He found that the stomach of a cock in twenty-four hours broke off the angles of a piece of rough, jagged glass, without laceration or wound. A leaden ball, into which twelve strong tin needles were firmly fixed, with their points projecting about a quarter of an inch from the surface, was then covered with a case of paper, and forced down the throat of a turkey. The animal discovered no symptoms of uneasiness, and at the end of a day and a half, when the stomach was examined, the points of the twelve needles were broken off close to the surface of the ball, except two or three, which projected a little. Two of these points were discovered among the food; the other ten had probably passed out of the body.

In another experiment, still more cruel than this, twelve small lancets were fixed, in a similar manner, into a leaden ball, and forced down the throat of a turkeycock. After eight hours, the stomach was opened, but nothing appeared except the naked ball, the lancets having been broken to pieces. The stomach itself was found perfectly sound and uninjured in both these experiments.

It is common, in the gizzards of many birds, to find small stones, which have been supposed to assist in breaking down grain and other hard substances into small fragments, to prepare the way for their digestion. Spallanzani has endeavored to prove that the muscular action of the gizzard is equally powerful without the stones. In a number of pigeons which he had fed from the egg himself, so as to prevent them from obtaining stones, he found that tin tubes, glass globules, and fragments of broken glass were acted upon in the same way as in ordinary circumstances; and this happened also without any laceration of the stomach. It is the opinion, however, of the best physiologists, notwithstanding these experiments, that stones are extremely useful in the comminution of grain and other substances which constitute the food of fowls, though not absolutely essential.

2. In stomachs of an intermediate kind, such as those of crows, ravens, &c., the power and action of their coats upon substances contained within them, were found to be greatly inferior to those of the strong muscular stomachs. But little alteration was produced upon the tubes of tin; but, when made of lead, they were evidently compressed and flattened. When unbroken grains and seeds were inclosed in perforated tubes and thrust into their stomachs, no change whatever was produced; no solution appeared to have taken place. But when the same substances were bruised into a coarse flour, so as to get rid of their husks, a very sensible diminution of their bulk took place, and on being several times introduced, they were finally entirely dissolved. Wheat and beans, when eaten voluntarily by the crow, offered similar phenomena. Before swallowing, the animal set them under its feet, and broke them in pieces by repeated strokes of its beak; and then they were very well digested. But when the same seeds were swallowed entire, they were generally

vomited up, or voided unaltered. Similar experiments were made with French beans, peas, nut-kernels, bread-apples, and different kinds of flesh and fish; and corresponding results were obtained.

'3. Spallanzani finished his experiments on digestion with those animals which have thin, membranous stomachs, as man, quadrupeds, fishes, reptiles, and some birds. In these, the coats of the stomach seemed to have little or no mechanical action upon their contents; the gastric juice being fully sufficient to break down the food and reduce it to a pulp.

'With regard to man, Dr. Stevens, in an Inaugural Dissertation concerning digestion, published at Edinburgh, in the year 1777, relates several experiments upon a German who gained a miserable livelihood by swallowing stones for the amusement of the people. He began this strange practice at the age of seven, and had at that time continued it about twenty years. He swallowed six or eight stones at a time, some of them as large as a pigeon's egg, and passed them in the natural way. Dr. Stevens thought this poor man would be an excellent subject for ascertaining the solvent power of the gastric juice in the human stomach, and accordingly made use of him for this purpose. He made the German swallow a hollow, silver sphere, divided into two cavities by a partition, and perforated with a great number of holes capable of admitting an ordinary needle. Into one of these cavities he put four scruples and a half of raw beef, and into the other five scruples of raw bleak. In twenty-one hours the sphere was voided, when the beef had lost a scruple and a half, and the fish two scruples. A few days afterwards, the German swallowed the same sphere, which contained, in one cavity, four scruples and four grains of raw beef, and, in the other, four scruples and eight grains of boiled. The sphere was returned in forty-three hours; the raw flesh had lost one scruple and two grains, and the boiled one scruple and sixteen grains. Suspecting that, if these substances were divided, the solvent would have a freer access to them, and more of them would be dissolved, Dr. Stevens procured another sphere, with holes large enough to receive a crow's quill. He inclosed some beef in it, a little masticated. In thirty-eight hours after it was swallowed, it was voided quite empty. Perceiving how readily the chewed meat was dissolved, he tried whether it would dissolve equally soon without being chewed. With this view, he put a scruple and eight grains of pork into one cavity, and the same quantity of cheese into the other. The sphere was retained in the German's stomach and intestines forty-three hours; at the end of which time, not the smallest quantity of either pork or cheese was to be found in the sphere. He next swallowed the same sphere, which contained, in one partition, some roasted turkey, and some boiled salt herring in the other. The sphere was voided in forty-six hours; but no part of the turkey or herring appeared; for both had been completely dissolved. Having discovered that animal substances, though inclosed in tubes, were easily dissolved by the gastric juice, the Doctor tried whether it would produce the same effect upon vegetables. He therefore inclosed an equal quantity of raw parsnip and potato in a sphere. After continuing forty-eight hours in the alimentary canal, not a vestige of either remained. Pieces of apple and turnip, both raw and boiled, were dissolved in thirty-six hours.

'The German left Edinburgh before the Doctor had an opportunity of making a farther progress in his experiments. He therefore had recourse to dogs and ruminating animals. In the course of his trials upon the solvent power in the gastric fluid of dogs, he found that it was capable of dissolving hard bones, and even hard balls of ivory; but that in equal times very little impression was made upon potatoes, parsnips, and other vegetable substances. On the contrary, in the ruminating animals, as the sheep, the ox, &c., he discovered that their gastric juice speedily dissolved vegetables, but made no impression on beef, mutton, and other animal bodies. From these last experiments, it appears that the different tribes of animals are not less distinguished by their external figure, and by their manners, than by the quality and powers of their gastric juices. Dogs, in the state of nature are unable to digest vegetables, and, in a state of nature, sheep and oxen cannot digest animal substances. As the gastric juice of the human stomach is capable of dissolving, nearly with equal ease, both animals and vegetables, this circumstance affords a strong, and almost an irresistible, proof, that Nature originally intended man to feed promiscuously upon both.' *

An opportunity of examining the process of digestion in a more satisfactory manner than by these experiments has been since afforded in the case of a Canadian, Alexis St. Martin, in whom a large opening into the stomach, caused by a wound of this organ, remained permanently open after he had otherwise recovered. Through this opening, the state of the stomach during digestion, and the mode in which this process takes place, were observed by Dr. Beaumont, who has published an interesting account of his researches. They serve to confirm the opinion previously entertained, that in the stomach the food is dissolved by the agency of the gastric juice; that this is capable of acting in the same manner out of the body as in it; that during the process the food is constantly subjected to a species of churning or peristaltic motion, by which it is in the first place thoroughly mixed with the gastric juice, and then the portions of it as they are dissolved and converted into chyme, gradually pass out of the stomach into the intestines. This motion hastens and facilitates the solution, in the same way as stirring hastens that of sugar or salt in water.

A great variety of other facts were determined by Dr. Beaumont; but, though highly interesting in their relation to physiology and disease, they are rather suited to professional treatises than to one intended chiefly for the general reader.

'Living animals, as long as the vital principle remains in them, are not affected by the solvent powers of the stomach. "Hence it is," Mr. Hunter remarks, "that we find animals of various kinds living in the stomach, or even hatched and bred there; but the moment that any of these lose the living principle, they become subject to the digestive powers of the stomach.† If it were

* Notwithstanding these experiments, of the accuracy of which there is no reason to doubt, it is unquestionable, as before stated, that animals can be accustomed to food very different from that which is most natural to them.

† It is nevertheless true that most animals when taken into the stomach alive are killed and then digested. This is the case with raw oysters. It was also found by Dr. Stevens in the experiments already related, that leeches and earth-worms, when inclosed in spheres and swallowed by his German subject, were completely dissolved by the action of the gastric juice.

possible, for example, for a man's hand to be introduced into the stomach of a living animal, and kept there for some considerable time, it would be found that the dissolvent powers of the stomach could have no effect upon it; but if the same hand were separated from the body, and introduced into the same stomach, we should then find that the stomach would immediately act upon it. Indeed, if this were not the case, we should find that the stomach itself ought to have been made of indigestible materials; for if the living principle was not capable of preserving animal substances from undergoing that process, the stomach itself would be digested. But we find, on the contrary, that the stomach, which, at one instant, that is, while possessed of the living principle, is capable of resisting the digestive powers which it contains, the next moment, namely, when deprived of the living principle, is itself capable of being digested, either by the digestive powers of other stomachs, or by the remains of that power which it had of digesting other things."

'When bodies are opened some time after death, a considerable aperture is frequently found at the larger extremity of the stomach. "In these cases," says Mr. Hunter, "the contents of the stomach are generally found loose in the cavity of the abdomen, about the spleen and diaphragm. In many subjects, this digestive power extends much farther than through the stomach. I have often found, that, after it had dissolved the stomach at the usual place, the contents of the stomach had come into contact with the spleen and diaphragm, had partly dissolved the adjacent side of the spleen, and had dissolved the stomach quite through; so that the contents of the stomach were found in the cavity of the thorax, and had even affected the lungs in a small degree."'

The ultimate purpose of the function of digestion is the conversion of the aliment taken, into blood. All animals have blood, but it is only among the higher classes that its peculiar qualities have been accurately observed. It appears, in man, like a homogeneous fluid of a red color; but it contains within itself the materials necessary to the composition of all the organs of the body, and the different organs select and separate from it those which are suited to their particular purpose. These materials, by an inherent, but most mysterious, power, are then moulded into the appropriate textures, and enter into the composition of the part.

The blood, although apparently so homogeneous, no sooner ceases to circulate than it spontaneously undergoes a variety of changes. If drawn into a vessel, and suffered to remain at rest, it speedily passes into the state of a soft solid. This is its coagulation. After a while it separates into two portions, like curdled milk. One is a yellowish liquid called serum. The other is still a soft solid of a deep red color, called the clot or crassamentum.

If the serum be exposed to a heat of about 160°, it coagulates in its turn, like the white of an egg when boiled, with which, indeed, its composition is nearly identical. From this coagulum a thin fluid may also be separated, which does not coagulate by heat.

The crassamentum, when separated entirely from the serum, becomes much firmer in its consistence, and resembles somewhat the muscular flesh of animals. It is also capable of being separated into two parts. By washing it repeatedly in water, it gradually loses its red color, and becomes nearly white, whilst the coloring matter is wholly transferred to the water. This is found, by examination under the microscope, to consist of small particles of a flattened globular shape like discs or rings. These are the red globules. They are heavier than the other parts, and would settle to the bottom did the blood remain in a fluid state. Indeed, when coagulation takes place slowly, the lower part of the clot is found to contain them in much larger proportion than the upper. Their diameter, which is not uniform, is stated by the best observers to be from $\frac{1}{2800}$ to $\frac{1}{4000}$ of an inch.

It is worthy of remark, that the blood globules vary much in size and shape in different animals, and this without any intelligible relation to the size or character of the individual. Thus in the Mammalia the diameter is found to vary from about $\frac{1}{5000}$ to $\frac{1}{1200}$ of an inch; and whilst in the mouse it is about $\frac{1}{4000}$, in the elephant it is but $\frac{1}{2750}$, not double the size, and in some of the large ruminants it is much smaller. In Birds, generally the globules are larger than in Mammalia, and in Reptiles, larger still. It is observable that in the Mammalia, with a few exceptions, the globules are round, but in Birds and Reptiles oval. No known connection can be traced between these differences and the condition of the different species as to food, habits, or mode of life.

A great variety of other particulars are known about the blood, but these are all that it is necessary to state for the present purpose. In the nutrition of some organs, as the muscles, the skin, and the hair, little more is required than to separate some of these substances into which the blood so readily divides, and give them an organic form; whilst in others, as the bones, the glands, the nerves, and the brain, beside the separation of the proper materials, a much more elaborate process takes place, by which a new texture is manufactured, very unlike, in its characteristics, any of the forms which the blood spontaneously assumes.

From the blood are formed not only all the organs of the body but also all its fluids. The tears, the saliva, the sweat, the gastric juice, the bile, are all separated from it by different organs. Some of them, like the sweat and the tears, seem to be little more than the simple straining off of its watery and saline ingredients; whilst others, as the gastric juice and the bile, imply a peculiar chemical combination of a very curious and wonderful character.

The constituent parts into which the blood is thus divided are known as its proximate or secondary elements, and they are, as has been intimated, directly concerned in the formation of the different textures. But the blood is capable of an analysis of another kind, by which it is reduced to its chemical ingredients. Of these, there are twelve in number constantly present, beside some others that are occasionally detected. They are carbon, oxygen, hydrogen, azote or nitrogen, phosphorus, sulphur, iron, chlorine, potassa, soda, lime, and magnesia. These are called the primary or ultimate elements, and more or less of these, combined in different proportions, constitute the secondary or proximate elements. The greater part of the bulk of the proximate elements is made up of the four first-named of the ultimate, namely, carbon, oxygen, hydrogen, and nitrogen, and, consequently, they are apt to be regarded as the most essential. Strictly speaking, this is not the case. Those existing in a smaller proportion are probably as necessary to the complete elaboration of the textures as those existing in a larger. Thus phosphorus may be as necessary to the composition of the brain, lime to that of the bones, sulphur to albumen, and iron to the red globules, though present in very small quantities, as the above-named four elements are in order to make up the chief bulk of the same parts.

The secondary or proximate elements of the blood are taken into the body already manufactured by the plants or animals which furnish our food. Our aliments, from whatever source derived, are very similar to each other in their intimate composition, and the process of digestion does not so much create them as give to them an appropriate form and structure. Milk, the only substance which seems to be prepared solely as aliment for the higher animals, may be taken as a type of the true constitution of food, that is, as containing every ingredient which is essential to the formation, nourishment, and growth of all the textures. Milk contains, 1. whey, which includes some albumen and a certain proportion of sugar; 2. curd, which is also albuminous but approaches in its character to the coagulum or fibrine of the blood; 3. cream, an oleaginous ingredient; and 4. water, as a diluent of the whole. These correspond to and represent very accurately the essential character of all the different aliments which are taken as food by man and the higher animals. Into the composition of all enters, in the first place, a large proportion of water, which constitutes the greatest part of the bulk of every living thing; 2. saccharine aliments, which include not only sugar, properly so called, but also all those substances in their chemical composition analogous to sugar, such as the various edible grains, rice, arrowroot, and the vegetable acids; 3. the albuminous aliments, as the flesh of animals, the eggs of birds, the gluten of wheat, and certain portions of other grains and seeds; 4. the oleaginous aliments, as butter, fat, and oils of every kind, both vegetable and animal, and substances analogous to oils, as wine, and alcohol, cider, and other fermented liquids.

These classes are capable of many subdivisions, but all the articles upon which we live may be arranged under one or the other.

Beside these, many substances not entering into either class are employed with our food, either to give it taste or to stimulate the stomach. Such are mustard, pepper, cinnamon, and other articles of the same kind. They are called condiments. Among these is usually included common salt. This stands, however, upon a somewhat different ground from the other condiments, since it is a mineral substance, and is not digested, but enters unchanged into the composition of the blood and textures. It enters, indeed, more or less into the composition of most articles of food, but not usually in sufficient quantity to supply the necessities of the system. Consequently it is almost universally added to food, and a demand is felt for it not only by man but by many animals. It is sought with great avidity, especially by those residing in the interior of continents. In the interior of Africa it is regarded as a great luxury, the natives prize it as children sugar, and they use as a substitute an impure carbonate of soda, which is obtained from one of their lakes. The excess and deficiency of salt may either of them be productive of disease.

The quantity of food required by man and other animals varies very much with age and with the kind of life which they lead. Young animals require more in proportion to their bulk than older, because this is the period of growth, and the rate of growth is almost in an inverse ratio to the age. A new-born child doubles its weight frequently in the course of a few months; a child five years old does not double it in as many years, and the rate of increase is less and less as life advances, till it becomes stationary. Finally in old age the body usually diminishes in size. But the rapidity of growth is much greater in many of the lower animals. There are some worms so small when they first come from the egg, that it requires from twenty-five to thirty of them to weigh a grain. After twenty-four hours, they have so increased in size that one will be found to weigh seven grains, that is to say, their bulk has increased about two hundred times in the course of one day. In order to this they are constantly feeding. This is an extreme case; but in the larvæ of many insects, as the common caterpillar, a great rapidity of growth may be observed. In general, the short-lived animals increase in size much faster than those whose term of existence is prolonged.

CHAPTER II. (W.)

CIRCULATION AND RESPIRATION.

In Man, as has been already stated in the Introduction, the circulation is double, and is carried on by a double heart, or, in fact, by two hearts, which, though united together in one mass, are yet entirely distinct in their office. One heart receives the blood by veins from the body, and sends it by arteries to the lungs; this is the right side of the organ. The other receives it by veins from the lungs, and sends it by arteries to the body; this is the left side. The blood thus makes two circuits, each beginning and terminating at the heart, and these two circuits make up the complete circulation. (Figs. 4 and 5.)

The time occupied for the circulation of any particular portion of blood, is astonishingly short. The heart expels about two ounces at every contraction; and of these about seventy-five take place in each minute. Supposing the quantity of the blood to be about thirty pounds, a quantity equal to this will pass through each side of the heart every three minutes, or twenty times an hour. But the motion of the blood is, under some circumstances, much more rapid than this; and there are facts which show that some portions of it may leave the heart and return to it in less than a minute.

The blood is not propelled through the arteries in a regular, even current, but by successive waves, which correspond to the contractions of the heart. Hence in a wound of one of these vessels, it flows in a series of jets, like the water from a forcing-pump. This motion causes the pulse. From the veins, on the contrary, it flows in a steady, continued stream, as we see it in a person who is bled.

The mode in which the arteries are distributed over the body, is worthy of notice. All wounds of them are attended with danger, and a division of the larger is often speedily fatal from loss of blood. They are secured from this in great measure, by the position they are made to occupy, and the manner in which they are distributed along the limbs. In the upper extremity, for instance, the main artery is protected by the collar-bone, under which it passes to the arm; thence it creeps down the inside of the bone, deeply buried beneath the flesh, to the elbow; and in a similar way, deeply covered by flesh, it goes down to the wrist. Everywhere the parts most exposed are free from large arteries, so that none but deep or unusual wounds are likely to reach them.

Another circumstance in this distribution is equally worthy of remark. It is obvious, if the vessel passed along the outside of a limb, or the outside of a joint, that, when the limb was bent, its coats would be put upon the stretch; it would be compressed, and the free passage of blood obstructed. This is prevented by the arrangement just described. For the same purpose, it does not run in a straight line, but has many turnings and windings in its course. This enables us to make violent and extensive motions without any compression, or strain of its coats, and in this way obstruction to the flow of blood, and injury to the vessels, are prevented.

The constant passage of the blood is necessary to the life and action of every organ. When interrupted, the part immediately ceases to perform its office, and if the interruption continue, it dies. So too, if the circulation of the vital organs be cut off, death of the whole body takes place at once; and hence it is, that ruptures or wounds or diseases of the heart cause death so suddenly.

But it is not only necessary that blood should be circulated to every part, but that this should be blood which has been subjected to the influence of the air in respiration. The venous or black blood is incapable of supporting life; and if respiration be suspended so that this is sent to the organs, instead of the red or arterial, the effect is as certainly fatal — though less speedily — as the suspension of the circulation altogether.

In the whole compass of Nature there is perhaps no single created thing which is so justly an object of attention and admiration as the heart, and this chiefly because its structure and mode of action are such that we almost perfectly understand them. To a cursory view it appears to be merely a mass of red flesh, not larger than the hand, and yet by a careful examination of its structure, there is found within its walls a mechanism which keeps up the motion of the blood, and is necessary every moment to the life of the system. There is no organ in which we more clearly see the connection between the object intended and the means by which it is accomplished. There may be some differences of opinion about minor details in its mechanical action; but as to the general purpose, the play of its valves, the uses of its cavities, and the course of the blood through them, all is as clear as the movements of a common pump.

It is worthy of notice that the structure of those natural objects which most closely resemble instruments of human invention, produces upon us the most forcible impression as evidences of design in their creation. No organs, for example, are so frequently adduced by the Natural Theologian as illustrations to enforce the great truths he would establish, as the eye and the heart. There are none which, in the principles upon which they are constructed, resemble so nearly pieces of mechanism contrived by man. The eye is a perfect optical instrument, and may be very closely imitated, except as to that mysterious power by which it communicates with the mind. So too the heart, — although its power of contraction is derived from the vital forces, whose nature is equally mysterious,—propels the blood upon purely hydrostatic principles; and its valves resemble, in the office they perform and the mode in which they determine the current of the blood, those which are constantly employed, for a great variety of purposes of an analogous nature, in the arts. It is only an object of greater admiration than the eye, inasmuch as its office is so much more important, and its connections with other parts concerned in the circulation so complicated and yet so clear.

It seems at first singular that those works of the Deity should excite so much of our admiration, which come the nearest to our own humble inventions. Yet it is an undoubted fact. It is explained by reflecting that in such cases we understand clearly the connection between the means used and the end obtained; and we understand it because the means are like those we have used, and the end analogous to those we have sought. In other organs it is not so. The conversion of food in the stomach and intestines into blood, is as wonderful a process, so far as the end obtained is concerned, but we know very little of the manner in which the means employed bring it about. The heart almost declares its own office, but there is nothing in the structure of the stomach, or the known properties of the gastric juice, to suggest the remarkable transmutation they effect. No one object in Nature is probably in itself more indicative of creative power and wisdom than another. But we understand some far better than others; and in proportion as we comprehend, we admire.

By respiration the blood is exposed, in its passage through the lungs, to the influence of the air, and by this influence some change is effected, which restores the vitality it has lost in its circulation through the rest of the body.

By the air is meant that common elastic fluid which envelops the whole earth, and extends to a certain distance from its surface. It constitutes what is called the atmosphere. By its weight, its compressibility, and its pressure in all directions, it insinuates itself into every vacuity; and its presence is absolutely necessary to the existence of every vegetable and animal. In order, however, to understand the manner in which it contributes to the support of living things, it is necessary to know something of its composition.

Although the air, as we breathe it, seems to be a simple and homogeneous fluid, it is in fact composed of two distinct constituent or elementary parts, upon the mixture or combination of which its adaptation to the preservation of life depends. It contains, besides these, some other ingredients of minor importance. These main elements are two permanently elastic fluids or gases, called oxygen, and nitrogen or azote. Atmospheric air contains about twenty-three parts, by weight, of the former, and seventy-seven of the latter, out of one hundred; or, since oxygen is the heavier of the two gases, twenty-one, by measure, of oxygen, and seventy-nine of azote. It is upon the oxygen of the air, that its fitness for supporting animal life depends; for, when an animal is confined in a small quantity of air till this is exhausted, it dies from suffocation, although the azote remains unaltered.

No animal can exist in an active state without air, but different classes of animals differ very much as to the manner in which the function of respiration is performed. The influence which the air exerts upon the blood, produces some change or imparts some principle, which renders it fit to be distributed to the body for its nourishment. In all the animals with red blood, namely, Mammalia, Birds, Reptiles, and Fishes, this change consists, so far as can be observed, in imparting to the dark-red or venous blood, which is sent to the lungs by the heart, a bright red or vermilion color. In this state, it is returned to the heart, and thence distributed throughout the body by the arteries.

In the Mammalia, the air is alternately drawn into the lungs, and expelled from them, by the action of the diaphragm and muscles of the ribs and abdomen. This is called the inspiration and expiration of the air, and is constantly going on. In the greater part of the animals of this class, if this process be stopped but for a few moments, death is the inevitable consequence; but in some species it may be suspended for a longer period. This is the case with the seal and the whale. Even men may acquire by habit the power of existing a considerable time without breathing, as is the case with the fishermen who dive for pearls; but many of the stories which have been related with regard to this subject are probably destitute of foundation.*

There are many other kinds of air or gas, which may be taken into the lungs, beside the atmospheric; but no other will support life. Even pure oxygen, and nitrous oxide, another gas containing oxygen, although they may be breathed longer than any other kinds of air, will finally prove fatal. It is only when oxygen is combined with azote in the proportions above mentioned, that it is adequate to the continued support of life.†

* Very marvellous accounts have been formerly given of the length of time during which persons have remained under water without death. The most reliable accounts of the performances of the pearl-fishers render it probable that they cannot endure an *entire* suspension of respiration of more than a minute and a half or two minutes.

† Water destroys the life of animals, merely by preventing the admission of air; it does not itself enter the lungs, or at most only in a very small quantity. There are some gases which operate in the same way. The windpipe is spasmodically closed against them, and they do not enter the lungs; such are carbonic acid gas, ammoniacal gas, chlorine or oxymuriatic gas, &c., when unmixed. Some other gases are inspired with sufficient ease, but produce death, either merely for the want of oxygen, as hydrogen and pure azote; or, in a cer-

The quantity of air ordinarily contained in the lungs of a common-sized man, immediately after an inspiration, has been calculated to be about two hundred and eighty cubic inches, and about forty inches are drawn in and thrown out at each inspiration and expiration; so that the whole mass of air is not changed at every breath, but a large proportion remains constantly present, and distends the lungs.

If the air which has been respired be examined, a change will be found to have taken place in its composition. A part of its oxygen has disappeared, and in its place is found about the same bulk of carbonic acid or fixed air. There is also a considerable quantity of watery vapor. This change is undoubtedly connected with the effect produced upon the color of the blood in respiration; and many have endeavored to give some account of the mode in which it takes place. But it is a process which we shall probably never be able fully to understand. A similar change is produced upon the air respired by all animals of whatever class.

The degree of heat in animals is generally proportioned to the vigor and quantity of respiration. The temperature of birds is higher than that of quadrupeds, and they consume a greater quantity of air. Reptiles and fishes have cold blood, and the amount of respiration in them is comparatively small. The same remark is true of all cold-blooded animals. The latest and most generally received theory of animal heat attributes its production to the actual combustion of carbonaceous matter in the body by its union with oxygen. Although there is no reasonable doubt that this explanation is mainly the true one, yet there are many facts which it does not account for, and it is probable there are other considerations to be had in view in order that it shall embrace all the phenomena.

It is a remarkable and interesting fact, that, notwithstanding the immense consumption of oxygen which takes place in order

tain sense, by poisoning the blood or destroying its vital properties, as carburetted and sulphuretted hydrogen, and carbonic oxide. Oxygen alone, as has been remarked above, and nitrous oxide, which contains a greater proportion of it than atmospheric air, are capable of supporting life for a considerable period, but finally prove fatal. The latter is celebrated for its intoxicating and exhilarating effects, when respired.

to the maintenance of animal life, the proportion of it present in atmospheric air remains exactly the same under all circumstances. The healthiness of different regions and different localities does not at all depend, as is often supposed, upon the character of the air in this respect. At the highest elevations above the earth, and at the lowest depths beneath it, the proportion of oxygen is the same. The poisonous miasmata of marshes, the noisome effluvia of hospitals, and infectious atmospheres which communicate disease, are all precisely alike in this respect. They depend for their noxious qualities upon the mixture of some other deleterious ingredient not always appreciable by chemical tests. Doubtless in closed rooms where many persons breathe the same air for a long period, and where many lights are burning, a deficiency of oxygen may exist. Still, the injurious effects of such an atmosphere are probably owing rather to the presence of other agents, especially carbonic acid and carbonic oxide, than to the diminished amount of oxygen.

Respiration commences immediately after birth, and at the same time a change is produced in the course of the circulation. Before birth, only a very small proportion of the blood is carried through the lungs; but after birth, and through life, the whole of it. The connection between the action of the lungs and that of the heart, is very close and important. The functions they perform are mutually dependent, and neither can go on alone. If the circulation cease by the cessation of the action of the heart, respiration is immediately interrupted. If, on the other hand, respiration be impeded, the heart does not stop at once; but as the dark, venous blood is no longer changed in its properties, as usual, in the lungs, it is returned to the heart in the same state, and is then sent through the body; and being unfit for the purposes of life, destroys it, by cutting short the action of all the organs. The effect of its contact upon the brain is an immediate suspension of life; and if the cause be long continued, it is never restored. But in many cases of this kind, as in persons apparently drowned, circulation and respiration may be renewed, if they have not been too long interrupted, by artificial respiration, and by the application of warmth and stimulating substances to the body.

Beside these uses of the function of respiration, it is made subservient to a number of other important purposes. All animals furnished with lungs express their wants, their affections and aversions, their pleasures and pains, either by words, or by sounds peculiar to each species. These are produced by different changes in the windpipe or canal through which the air is drawn into the lungs. The inferior animals are by this means enabled to maintain some sort of communication with others of the same species. But how far they are intelligible one to another, it is impossible to ascertain. 'On man alone, Nature has bestowed the faculty of speaking, or of expressing his various feelings and ideas, by a regular, extensive, and established combination of articulate sounds. To have extended this faculty to the brute creation, would not, it is probable, have been of any use to them; for, though some animals can be taught to articulate, yet none of them seem to have any idea of the proper meaning of the words they utter.

'Speech is performed by a very various and complicated machinery. In speaking, the tongue, the lips, the jaws, the whole palate, the nose, the throat, together with the muscles, bones, and cartilages of which these organs are composed, are all employed. This combination of organs we are taught to use when so young, that we are hardly conscious of the laborious task, and far less of the manner in which we pronounce different letters and words. The mode of pronouncing letters and words, however, may be learned by attentively observing the different organs employed by the speaker. By this means we are enabled to correct the various defects of speech, and even to teach the dumb to speak; for dumbness is seldom the effect of imperfection in the organs of speech, but generally arises from a want of hearing; and it is impossible for deaf men to imitate sounds which they never heard, except they be taught to use their organs by vision and by touching.

'When about to laugh, we make a very full inspiration, which is succeeded by frequent, interrupted, and sonorous expirations. When the titillation is great, whether it arises from the mind or body, these convulsive expirations sometimes interrupt the breathing to such a degree as to endanger suffocation. Moderate laughing, on the contrary, produces health; by agitating the whole body, it quickens the circulation of the blood, gives an inexpressible cheerfulness to the countenance, and banishes every kind of anxiety from the mind.

'In weeping, we employ nearly the same organs as in laughing. It commences with a deep inspiration, which is succeeded by short, broken, sonorous, and disagreeable expirations. The countenance has a dismal aspect, and tears are poured out. Weeping originates from grief, or other painful sensations either of body or mind. When full vent is given to tears, grief is greatly alleviated. Both laughing and weeping have been reckoned peculiar to man,' and in the proper sense of these terms, this idea is well founded. Animals do not seem capable of those emotions which occasion them in man. They have no perception of humor, no sense of the ludicrous, on the one hand, nor of the moral sentiment of grief or sorrow on the other. They are simply capable of pleasure and pain, and these they indicate by symptoms or cries which are understood by the individuals of each species, and in many instances by man. 'A dog, when hurt, complains in the bitterest terms; and when he is afraid, or perhaps melancholy, he expresses the situation of his mind by the most deplorable howlings. A bird, when sick, ceases to sing, droops the wing, abstains from food, utters melancholy, weak cries, and exhibits every mark of depressed spirits. By this means, animals intimate the assistance they require, or soften those who maltreat them. Their plaintive cries are sometimes so affecting as to disarm their enemies, or to procure the aid of their equals. On the other hand, when animals are pleased or caressed, they discover, by their countenance, by their voice, by their movements, unequivocal symptoms of cheerfulness and alacrity of mind. Thus the expressions of pleasure and pain by brute animals, though not uttered in the precise manner with those of the human species, are analogous, and answer the same intentions of Nature.'

The respiration of Birds is carried on by an arrangement of the lungs very different from that of the Mammalia. They are enabled to transmit air to almost every part of their bodies, by means of membranous sacks or bags, which receive it from the lungs through certain orifices or passages on the surface of these organs. The lungs themselves are firmly attached to the ribs, and are almost incapable of dilatation or contraction, but the air passes through them into the sacks by the combined action of various muscles. In this way it is diffused not only throughout the thorax and abdomen, but extends even to the cavities of many of the bones, which are distinguished from the others by their lightness, their white color, and the absence of any bloody matter or marrow in their cavities.

This provision answers several important purposes. It renders birds lighter, in proportion to their bulk, than animals whose bones are filled with marrow or other solid substances, and thus gives them some advantage in flight; and generally in birds of the longest and highest flights, as eagles, this extension or diffusion of air is carried farther than in others. But a more important object of it probably is, to contribute to the muscular strength of these animals, by producing a very extensive operation upon the blood. The motions of birds in flight require a much greater expenditure of power, than those of walking or running in other animals. This power depends upon the circulation of the red, arterial blood in the muscles which exert it, and in order to increase the proportion of this, the influence of the air is carried over the whole system, instead of being confined to the lungs alone. It has been found that birds consume, in proportion to their size, more air than quadrupeds; and this arises from its extensive influence upon the blood. Thus, two sparrows were found by Lavoisier to require as much for their existence as a guinea-pig, an animal many times as large. Another use ascribed to this arrangement by Mr. Hunter, is that of acting, in some degree, as a reservoir of air, to prevent the necessity of frequent respiration, which may be supposed inconvenient to birds while moving rapidly on the wing.

The voice of birds is more remarkable and beautiful than that of any other animal except man; and, on account of the large quantity of air which they have at command, it is much more powerful. But the sounds uttered by man and quadrupeds are produced by an organ situated at the top of the windpipe, called the *larynx*, with the assistance of the mouth; whilst, in birds, the organ of voice, or larynx, is situated at the spot where it divides into two parts to go to the lungs on each side, that is to say, at the bottom of the throat. The variations of note are produced by a little membrane in the tube, which is made to vibrate by the air; and by means of a number of muscles, which either tighten or relax it, it is made to give the various notes. Hence, in singing, birds seldom close or make any motions with their beaks. That the voice is produced at this place, is proved by the fact that it sometimes continues for a short time after the head has been removed. The other parts of the windpipe are not, however, without their use. Some changes of tone are produced by shortening or lengthening it, and others by contracting or enlarging its upper opening into the mouth. The organ of voice, in fact, resembles in many respects a musical instrument, and the excellence and beauty of the notes of birds depend very much upon imitation and education. The nightingale, if secluded in a cage when young, never sings so perfectly as in the wild state, unless exposed in a place where it can hear the song of those which are at liberty. Many birds are capable of imitating a great variety of sounds, and some have been taught to sing very accurately tunes of human composition, merely by playing them upon some instrument in their hearing.

'The lungs of Reptiles do not consist, like those of the Mammalia and Birds, of a solid organ penetrated in every direction by the air tubes, but of a number of bags of a membranous texture, into which the air is conveyed. In some, this is effected by the motion of the ribs and muscles of the abdomen, as in serpents and lizards. In others, as in frogs and tortoises, the air is swallowed. Respiration in these animals is not performed so regularly and constantly as in the higher classes. Only a comparatively small proportion of the blood is subjected to the influence of the air at once; and they can subsist for a very considerable time without breathing, though its suspension at length destroys them. Tortoises have been known to live more than a month with their jaws tied closely together, and their nostrils filled with sealingwax. A toad lived for five days in a jar containing about a hundred cubic inches of air. In forty inches, another toad lived for twenty-four hours, and a frog for fifty-nine. This is many times longer than a warm-blooded animal could exist under the same circumstances.'

The temperature of the bodies of reptiles is generally that of the air and water in which they are found. Still they have the power of resisting, during life, both very high and very low temperatures; and as their heat is seldom, under any circumstances, raised to a degree near to that of our bodies, they are designated as cold-blooded animals. This circumstance proceeds, probably, in some way from the limited quantity of their respiration; and with the same cause is connected their inferior power of motion, their tendency to the dormant state, and in general their low degree of vital power.

The respiration of Fishes is carried on by means of gills or branchiæ, to which the air is applied through the medium of the water. Every portion of water contains a certain quantity of air combined or mixed in some way with it, and by this means is made capable of supporting respiration. A current of water is constantly passed over the gills by the action of the mouth, and produces the requisite change upon the blood circulating through them. This change is of the same kind with that taking place in the warm-blooded animals. It arises from the influence of the oxygen in the atmospheric air; and, if the water be examined after fishes have respired it, the air it contains will be found to have undergone a similar change of composition with that breathed by quadrupeds and birds.

'When a free communication with the external air is prevented by ice, or by artifice, fishes immediately discover symptoms of uneasiness, and soon perish. Ælian informs us that, in winter, when the river Ister was frozen, the fishers dug holes in the ice; that great numbers of fishes resorted to these holes; and that their eagerness was so great that they allowed themselves to be seized by the hands of the fishermen. Rondeletius made many experiments on this subject. If, says he, fishes are put into a narrow-mouthed vessel filled with water, and a communication with the air be preserved, the animals live, and swim about, not for days and months only, but for several years. If the mouth of the vessel, however, be closely shut, either with the hand or any other covering, so that the passage of the air is excluded, the fishes suddenly die. Immediately after the mouth of the vessel is closed, the creatures rush tumultously, one above another, to the top, contending which of them shall soonest receive the benefit of the air. In the shallow parts of rivers, when frozen, many fishes are found dead. But when parts of a river are deep or rapid, the fishes fly from the ice, and by this means avoid destruction.

'These, and similar experiments, have been repeated by Mr. Willoughby and many other modern authors; and they have uniformly been attended with the same event. A carp, in a large vessel full of water, was placed in the receiver of an air-pump. In proportion as the air was exhausted by working the pump, the surface of the animal's body was covered with a number of bubbles. The carp soon breathed quicker, and with more difficulty. A little after, it arose to the surface in quest of air. The bubbles on its surface next disappeared; the belly, which before was greatly swollen, suddenly collapsed; and the animal sunk to the bottom, and expired in convulsions.'

Air is distributed in the bodies of Insects by a great number of tubes or canals, called *tracheæ*, which convey it to every part. These communicate with the external air by means of openings called *stigmata*, which furnish a constant supply. That these organs are destined for the transmission of air, has been proved by repeated experiments; for when stopped up by the application of oil, or other unctuous substances, the animals soon lose their existence. In some insects they protrude externally to some distance from the body, and have the appearance of one, two, or three tails; and in others they arise from the back and sides.

'In contemplating the parts of animals, when the uses of these parts are not apparent, we are apt to deceive ourselves by rashly supposing them to answer purposes for which they were never intended by Nature. Impressed with this idea, M. de Réaumur was not satisfied with the notion of Godart and others, that the long tails of certain worms were intended to keep them steady in their motions, and prevent them from rolling. Réaumur observed that these worms or grubs could lengthen or shorten their tails at pleasure, but that they were always longer than the animal's body.

Because these tails have some resemblance to that of a rat, he distinguishes the animals by the name of *rat-tailed worms.* These worms are aquatic, and never appear on dry ground till they are about to undergo their first transformation. Réaumur, in order to observe their economy more closely, collected a number of them into a glass vessel filled two inches high with water. At first they were considerably agitated, each seemingly searching for a proper place of repose. Some of them swam across, others attached themselves to the sides, and others rested at the bottom of the vessel. In a quarter of an hour they were almost entirely tranquil, and Réaumur soon discovered the real use of their long tails. Upon examining the vessel, he found that each of the animals, in whatever situation it was placed, extended its tail exactly to the surface; that, like other aquatic insects, the respiration of air was necessary to their existence; and that the tail, which is tubular, and open at the extremity, was the organ by which this operation was performed. In this experiment, the distance from the bottom to the surface was two inches, and, of course, the tails were of the same length. To discover how far the animals could extend their tails, he gradually augmented the height of the water, and the tails uniformly rose to the surface, till it was between five and six inches high. When the water was raised higher, the animals immediately quitted their station at the bottom, and either mounted higher in the water, or fixed upon the sides of the vessel, in situations which rendered it convenient for them to reach the surface with the points of their tails. These tails consist of two tubes, both of which are capable of extension and contraction. The first tube is always visible; but the second, which is the proper organ of respiration, is exerted only when the water is raised to a certain height. Through this tube the air is conveyed into two large tracheæ or windpipes within the body of the animal. When the tails are below the surface, they occasionally emit small bubbles of air, which are visible to the naked eye; and immediately are extended to the surface for fresh supplies. These worms pass the first and longest part of their lives under water; when near the time of their transformation, they leave the water, go under the ground, and are there transformed into chrysalids; and, lastly, from this state they are transformed into flies, and spend the remainder of their existence in the air.

'Another species of aquatic worm merits attention. They frequent marshes, ditches, and stagnating waters. Their general color is a greenish brown. Their bodies consist of eleven rings; and their skin is not crustaceous, but rather resembles parchment. Though these animals, before their transformation into flies, live in water, air is necessary to support their principle of life; and the apparatus with which Nature has furnished them for that important purpose, deserves our notice. The last ring or termination of their bodies is open, and serves as a conductor of air. From this last ring proceed a number of hairs, which, when examined by the microscope, are found to be real feathers with regular vanes. In particular situations, they bend the last ring in such a manner as to reach the surface of the water or mud in which they are placed. These feathers prevent the water from entering into the tube, or organ of respiration; and when the animal raises the termination of its body to the surface, in order to receive air, it erects and spreads the feathers, and by this means exposes the ends of the tube to the atmosphere. When cautiously cut open, two large vessels, or tracheæ, appear on each side, and occupy almost one half of the body. Both of these windpipes terminate in the open tube, or last ring. Though these worms are furnished with organs of respiration, and actually respire air, yet M. de Réaumur discovered that some of them could live more than twenty-four hours without respiration.

'So anxious is Nature to provide animals, in every state of their existence, with air, that, after the transformation of many insects into chrysalids, she creates instruments for that purpose, which did not exist previous to their transformation. The rat-tailed worms, formerly mentioned, soon after they are transformed into chrysalids, instead of a soft, pliable skin, are covered with a hard, crustaceous substance, seemingly impervious to the air; and the tail, which was the windpipe of the animal in its first state, gradually vanishes. In a few hours, however, four hollow horns shoot out, two from the fore, and two from the hind part of what was the head of the animal. These horns, which are hard and tubular, are discovered to be real windpipes, destined for the introduction of air into the chrysalis, a state in which the animals have the appearance of being almost totally dead, and, of course, would seem to have little use for respiration. It is likewise discovered that these horns, which pierced the hard exterior covering, terminate in as many tracheæ in the body of the animal. This fact affords a strong example of the necessity of air for sustaining the principle of life, even in its lowest condition. After these animals pass from the chrysalis state to that of flies, they are deprived both of their tails and horns. But Nature, in this last stage of their existence, has not left them without proper resources for the introduction of air into their bodies. Instead of protuberant tracheæ in the form of tails or horns, they now, like other flies, receive air by means of stigmata, or holes, variously disposed over different parts of the body.

'The nymphs of the libellula, or dragon-fly, respire water by an aperture at the termination of their bodies. These nymphs sometimes throw out the water, at certain intervals, with such force that the stream is perceptible at the distance of two or three inches from their bodies. When kept some time out of the water, the desire or necessity of respiration is augmented, and accordingly, when replaced in it, inspirations and expirations are repeated with unusual force and frequency. If you hold one of these nymphs in your hand, and apply drops of water to the posterior end of its body, it instantly, by an apparatus similar to the piston of a pump, sucks it in, and the dimensions of its body are visibly augmented. This water is again quickly thrown out by the same instrument. But though this insect respires water, air seems to be not the less necessary to its existence; for, like other insects, the whole interior part of its body is amply provided with large and convoluted tracheæ; and, externally, there are several stigmata destined for the introduction of air.

'The worms and nymphs of the ephemeron flies merit attention. They have received the denomination of *ephemeron* because very few of them survive the day in which they are transformed into flies. Many of them live not one hour after their transformation. When in the worm and nymph states, they generally live in holes near the surface of the water; and under these two forms, continue to grow till they are mature for passing into the last and shortest period of their existence. Swammerdam informs us that some of them remain three years under water, others two, and others one only.

'On each side of their bodies there are six or seven protuberances, which have the appearance of so many oars. With these instruments the animals describe arches in the water, first on one side, and then on the other, with astonishing rapidity. This circumstance led Clutius, and some other authors, to think that these protuberances were fins, or instruments of motion, and that the animals were fishes. But Réaumur remarked, that they moved these fins with the same rapidity when the animals were at rest as when they were in motion; and that, instead of fins, when examined by the microscope, he discovered them to be gills through which the creatures respire. Each gill consists of a short trunk, and two large branches or tubes, which give off on all sides a number of smaller ramifications, and are perfectly similar to the tracheæ of other insects. At the origin of every gill, two tracheæ penetrate the trunk, and are dispersed through the body of the animal.'

The Crustacea, the Worms, and Mollusca, respire by means of gills, which, although they differ in some measure from those of fishes, are formed upon the same plan. In a few instances they respire air by itself, but in general through the medium of water alone. In some animals of these classes the gills are situated upon the outside of their bodies, but commonly within. Many of the Radiata have no distinct organs for respiration; yet the air seems, in some way or other, absolutely necessary for their existence also, and probably penetrates their bodies, and acts upon their blood by means entirely unknown. These animals are all cold-blooded.

CHAPTER III. (W.)

ON THE CONNECTION OF ANIMALS WITH HEAT, LIGHT, AND ELECTRICITY.

The power possessed by animals of maintaining a temperature independent of the medium in which they live, has been already referred to. A certain degree of this power is probably universal, but it varies much in different classes, being least in the lower and greatest in the higher. In its most limited degree, it is shown by the fact that the animal resists the influence of cold and is not frozen so speedily as the substances around it, or as it would be itself after being deprived of life. But in the lower species, vitality is not destroyed even by freezing, as it is, for the most part, in the higher. In Fishes the temperature is usually that of the water in which they reside, except when this falls very low. It is then maintained at a few degrees above it. A few species, distinguished by unusual muscular activity, are capable of a still greater heat as compared with that of the water; even ten or twelve degrees. Some in the Arctic regions are known to have retained life even after having been imbedded for some time in ice.

In Reptiles the power of resisting the influence of cold is somewhat greater. The frog maintains a temperature of between thirty and forty degrees, when enveloped in ice reduced some degrees below the freezing point. In such cases the animal is surrounded by a thin covering of water, which the heat of its body prevents from being frozen.

The bodies of Insects are so small that it is difficult to observe their temperature accurately, except where they can be collected together in large quantities. There are some facts which seem to show that they have considerable power in this respect. From observations upon the temperature of bees in winter, it has been found that, when the inhabitants of a hive are in a quiescent state, their degree of heat does not vary much from that of the air. If, however, they are roused and become active, it rises immediately to seventy or eighty degrees, and this continues as long as the state of activity continues. This increase is probably owing to the greater energy of respiration and circulation attendant upon muscular action.

The circumstances according to which the temperature of insects varies, are still not perfectly understood. In the common caterpillar, for example, its increase of heat is not always connected with increased activity of function. While in an inactive condition, their temperature will sometimes rise above that of the air, though usually it is the same.* Many more and minute observations are necessary, before this subject can be fully comprehended.

The power of producing and keeping up the heat of animals, is closely connected with their life and health. This is particularly the case with the warm-blooded. This power is least vigorous at birth, and increases with age, till it is most perfect in the adult. It then again diminishes, and is deficient in old age. In order to prevent the disastrous effects of cold, animals in a state of nature usually produce their young in spring and summer, and in our own species, when this is not the case, with all the precautions taken, the mortality of very young infants is greater during the cold months than the warm. When life is not directly destroyed by causes diminishing the heat of the body, their continued influence depresses the vital powers and injures the constitution, laying the foundation for future disease. The idea, so prevalent, that children may be hardened by exposure, and by dressing as thinly as possible, is most pernicious,

* In examining the temperature of the common caterpillars which infest the apple-tree, it was found that at 6 A. M., the sun being bright, when the thermometer in the shade stood at 44° and in the sun at 63°, if introduced into a large mass of them collected together on the outside of their nest it rose to 87°; at 1½ P. M., the sun being obscured, and the air being at 54°, the thermometer, within the same nest, into which the animals had retired, rose to 70°: at 4 P. M., the air at the same degree, the temperature within was only 65°.

On several other days the result was mainly the same. The animals in each case were in a state of complete inactivity.

So far as such limited observations suggest any conclusion, they indicate that the generation of heat is greatest in the cool of the morning, while the animal is in a state of inactivity, but has crawled abroad to bask in the sun, and declines gradually in the course of the day.

with regard to their physical management. Those who have a robust constitution and an originally strong heat-making capacity, survive the ordeal, and the vigor which is natural to them is regarded as the result of the discipline to which they have been subjected. As a general rule, infants and children require to be more warmly clothed than adults, because not only is their heat-making power less, but their bodies, being smaller, are more rapidly cooled.

The heat-making power also varies with climate and season. It is greater in cold climates than in warm, and in winter than in summer. Repeated exposure to cold is best borne by those who, in the intervals of exposure, avail themselves of artificial heat; and those bear the cold best, who go into it well warmed and clothed. It is a mistake to suppose that those who live in houses insufficiently heated are best able to bear exposure abroad. This truth is well understood by the inhabitants of very cold climates. We are informed by Dr. Kane that the Esquimaux, who are frequently exposed to a temperature fifty or more degrees below zero, live in cabins whose heat is raised to more than ninety degrees. From this they go abroad at once into the external air, and are able to endure an almost incredible amount of hardship and cold.

By repeated exposure to cold, particularly when the body is not well warmed in the intervals, and under unfavorable circumstances as to clothing and food, the power of generating heat is diminished, and a person suffers from a less amount of exposure. Hence, the diseases produced by cold are more prevalent toward the latter part of winter and in spring, than in the autumn and early winter months. More protection from clothing is necessary to guard against injury in the former season than in the latter.

The power of generating heat is probably at its minimum at the beginning of summer, having been exhausted by the continued demand made upon it during the cold months. It accumulates during the summer, probably because the demand for it is so small, and is at its maximum in the beginning of winter. Hence it is safer, so far as health is concerned, to defer precautions against cold in autumn, both in our houses and clothing, than it is to leave them off in spring. We are somewhat deceived as to this by our sensations. The skin having been used to the temperature of winter becomes insensible to the feeling of cold, and this is apt to be mistaken for a power of enduring its effects. But its injurious effects are not the less likely to follow. So, too, persons insufficiently protected by clothing and artificial heat, as they experience the sensation of cold less, are supposed to be also less liable to its injurious effects on the health. This, however, is not the case.

Animals have certain relations to light, as well as to heat. With the luminousness of some insects, as the glowworm and the fire-fly, every one is familiar. The number of insects in whom this phenomenon is observed is quite large. In some, the light is intermittent and seems dependent upon the will of the animal, as in the common fire-fly; in others, as in the glowworm, it is more constant. One species of the latter, in which light is emitted from the edge of each articulation of the body, and also from the spiracles, is one of the most brilliant and beautiful natural objects. This light is often called phosphorescent, and in its color resembles the glow of phosphorus undergoing a slow combustion. There is, however, no reason for believing that it has any connection whatever with this process. The mode of its production is not understood, but it appears most probable that it is owing to a direct power of producing light on the part of the animal, analogous in principle to the production of heat and of electricity. It is not a more remarkable phenomenon than these, and not more inexplicable. Some singular examples have been recorded of the luminousness of the human countenance at the near approach of death, and it is not impossible that under various circumstances, at present unknown to us, many animal bodies may be capable of emitting light.

The most numerous of luminous animals are of the very lowest class, and inhabit the sea, especially within the tropics. So universally diffused are they, that all motion of the water, as by the passage of a vessel, the breaking of the waves, their ripple on the beach, the dip of oars, all give rise to flashes of light, and the wake of a ship is often marked as by a stream of fire.*

* M. Quatrefagues, in his "Rambles of a Naturalist," gives a vivid account

The absolute necessity of light to the health and development of plants is well known. It is hardly less so to that of animals. Its influence is most salutary in man, both upon the mind and body. It has been found, by actual experiment, that privation of light retarded or prevented the transformations of certain animals, and it has been observed that there are an unusually large number of deformed children among families in the narrow streets and dark cellars of cities. The patients in a large military hospital were found to present a much smaller mortality upon the side exposed to the sun than on the opposite, and a person who had large numbers of workmen in his employ asserts that the health of those occupied in rooms of a light color was distinctly better than in those of a dark.

A more free and frequent exposure to the influence of the sun's rays is probably one of the causes of the better health of those who live in the country, over those who live in the city; and of those who move about constantly in the open air, over those who work in close and darkened apartments. Two French regiments were once under orders to perform a long and toilsome journey of several hundred miles in the heat of summer. The commander of one, in order to spare his men the fancied danger from the heat of the day, performed his marches during the night. The other travelled by daylight. He reached the end of his journey with his men in good condition, having suffered only the usual necessary casualties of a long march; whilst the ranks of the other were thinned by disease and death. It is found, in

of this phenomenon, as occurring in the Mediterranean. His boat seemed as if opening for itself a passage through some fused and glowing liquid. Water poured from a bucket looked like redhot, molten lead. He is of opinion that during the period of reproduction certain microscopic animals among the Crustacea, Annelida, and Medusæ acquire the property of emitting light at each muscular contraction. Ehrenberg attributes the phenomenon to a special organ like that in the glowworm. It has also been supposed to proceed, in some cases, from the slow combustion of a peculiar secretion, by means of air admitted into the interior of the body. This has been thought to be confirmed by the facts that the light is extinguished when the animal is immersed in carbonic acid, and that when exposed in oxygen the same gas is produced. But these results are equally explained by the consideration that the influence of carbonic acid would necessarily suspend all vital operations, and upon these the evolution of light may depend; whilst the extrication of carbonic acid in the oxygen might be due to respiration, which in this case would not be interrupted.

the experience of army physicians, that the subjects of disease endure it better in open tents than in crowded hospitals; and an eminent military physician states that soldiers with fever encountered it more favorably while the army was in motion, and they were transported in wagons, than when it was stationary. Much of this difference is no doubt due to the more free ventilation which is thus ensured, but a part may also be fairly attributed to the salutary effect of light.

Regard should be paid to this in the management of the sick, and particularly in the case of chronic invalids. There are some cases in which there is a peculiar sensitiveness of the nervous system in general, or of the eye in particular, which may render the exclusion of light necessary in the sick-chamber. But, wherever possible, this should be avoided; and at any rate, it is certain that the practice so common in civilized society, of living in darkened rooms, is as injurious as it is disagreeable.

The evolution of electricity in the bodies of animals is a well established phenomenon. In some this takes place in so remarkable a degree that they are capable of communicating a distinct shock; and it is supposed that this is intended as a means of benumbing their prey, and of defence against enemies. These all belong to the class of Fishes. The most celebrated among them are the gymnotus, or electric eel, and the torpedo. The electricity is developed by means of an apparatus of a peculiar structure answering the purpose of a battery, composed of layers of membrane divided into hexagonal cells traversed again by various membranous partitions, all the cavities thus formed being filled with a medullary, pulpy substance, somewhat like that of the brain, and supplied very largely with nerves. The mode in which this apparatus serves to develop the electric fluid is not understood.

The shock given varies in degree according to the condition of the animal, and he may be so exhausted by repeated discharges as to render it very feeble. Advantage has been taken of this circumstance to aid in their capture. A number of horses are driven into the waters they inhabit. Their presence irritates the animals, who attack them with vigorous discharges, till they are exhausted of their power and become quite harmless. They are then taken easily by the hand.

It has been asserted that they are capable of communicating a shock for some distance through the water. Also that when one of them seizes upon the hook of a fisherman in rainy weather, a shock is communicated along the moisture of the line and rod to the hands. This, however, seems doubtful, as in ordinary cases it is necessary that their bodies should be touched in two places, in order to produce the necessary discharge. In this way a shock has been known to give rise to an electric spark, and to pass through a circle of several persons whose hands were joined.

Several species of Insects are believed to possess the same electrical power, and it is stated, by a late writer, that even among the very lowest of the animal kingdom, the Radiata, there is evidence of its existence. "I have seen," says he, "a polype seize two worms at the same time; and to reach them the arms were extended to such a degree of tenuity as scarcely to be perceptible without the aid of a lens; and the worms, though very lively, and struggling violently, were unable to break asunder these delicate instruments and escape, but in an instant were struck motionless. This phenomenon strikingly resembles the effect produced by the electric eel, and it is not improbable that the hydra, like that fish, kills its prey by an electric shock."

Electricity is also developed in the bodies of many animals, under different circumstances, and without any peculiar apparatus. Variations in the electric condition of our organs, and currents of the electric fluid, are indeed constantly taking place in connection with the performance of all our functions; but these are insensible to ordinary observation. In cold weather, electricity is often developed by the friction of certain articles of dress, especially if of silk, as in drawing off a stocking or glove. The fur of cats often presents the same phenomenon; but it is doubtful whether these cases indicate anything more than the accumulation of electricity according to its ordinary laws. In some individuals, however, a distinct and independent electrical power has been observed. An account was published, a few years ago, of a female in this country who possessed a power of emitting sparks from her person to surrounding bodies. More recently it appears that this is not an uncommon occurrence. It has been found in many families, that sparks were emitted when any metallic body was touched, as a shovel, or the stopcock of a gas lamp. Frequently, too, in the contact of persons, as in kissing, the same has been observed. So far as has been noticed, this takes place more especially in particular localities, as in certain streets of a city. A very remarkable exhibition of the discharge of electricity from the human body, takes place in the lighting of a gas lamp by the tip of the finger. This the writer has repeatedly witnessed. This phenomenon, however, is not due to the spontaneous development of electricity, as in the other instances referred to, but to its accumulation by some kind of friction, such as shuffling repeatedly over a woollen carpet, or lashing a person for some time with a silk handkerchief, while he stands upon an insulated stool. These phenomena, like those of ordinary electricity, are most successfully produced in particular states of the atmosphere, as in the cold, dry weather of winter. Still they are not peculiar to this, since Dr. Livingstone speaks of a hot wind in South Africa, blowing over the desert from north to south, so dry as to warp the best-seasoned furniture, and so highly electrical that a bunch of ostrich feathers, held a few seconds against it, becomes highly charged, and clasps the hand with a sharp cracking sound, whilst the movements of the natives in the thicket produce a stream of small sparks.

The electrical conditions of the atmosphere have undoubtedly a considerable effect upon the human frame. Many persons are seriously affected during a thunderstorm, under circumstances that preclude the supposition that the effects are owing to fear. There are those, also, that can predict a storm by a peculiar physical condition. Probably much of the influence of certain winds upon the system is owing to this cause. It is asserted, for example, that the sirocco, a wind very marked in its prostrating effects, is negatively electrical. The distinct character of the east wind of the Atlantic sea-coast of America, is, it is not unlikely, due to its electrical condition, since it cannot be explained either by its dampness or its temperature.

It seems probable, also, that the great sensibility possessed by many animals to atmospheric variations may be due to a nice perception of electrical conditions, and a consequent power of anticipating changes that are about to occur. It is very certain that many of them make provisions, and take precautions, which show them to possess some instinctive foresight that is utterly beyond any knowledge derived from the observation or the science of man.

CHAPTER IV. (W.)

MOTIONS OF ANIMALS.

All the functions of animal life are dependent for their performance, to a greater or less extent, upon motions in the organs which perform them. On examining the higher classes these motions are found to be of two kinds. First, those produced by the will of the individual in order to bring about some definite purpose, as to satisfy some appetite, to supply some want, to express some sentiment, or indicate some intention; such are those which produce the voice, and the movements of the limbs. Second, those which take place independently of any purpose or consciousness on the part of the individual; such are the motions of the heart, the stomach, and the bloodvessels, by which the vital functions are performed. These are under the direction of a principle independent of, and yet subservient to, the consciousness and will. These involuntary motions are, in their sphere, more complete and perfect than the voluntary. The principle which guides them is more unerring. Organs, ordinarily under the government of the will, pass sometimes in part under the influence of the involuntary principle, and corresponding motions take place, as in the eyes, the countenance, and limbs; and still further, motions which by frequent repetition become habitual, though at first entirely voluntary, pass at last under the same influence and become involuntary; such are the rapid motions of the musician, of some artisans, and in fact many others.

But though in the higher classes the distinction between these kinds of motion is so well marked, in the lower it is often not a little difficult to draw the line between them. Many of those external motions which in the former are clearly under the control of the will and the result of intention, in the latter afford no more indication of either, than does the contraction of the heart or the peristaltic movements of the stomach.

All voluntary motion is performed by muscles. Probably all involuntary motion is so also, but concerning this there has been some difference of opinion; though, as to the more important ones, as of the heart, the stomach, the alimentary canal, there is no doubt. Bones, tendons, and ligaments, constitute important portions of the moving apparatus. They represent the inert parts of a machine; the muscle, the mechanical power which puts the whole in operation.

The muscles compose a great part of the bodies of most animals. The flesh used as food consists chiefly of them. In quadrupeds, and in some parts of birds, they are red. In fishes, and in most of the lower animals, they are white or approaching to white. At first view, flesh appears like an unformed, indiscriminate mass, but by examination it is found capable of subdivision into a great number of perfectly distinct organs, each of which is a distinct muscle, whilst each muscle is itself a collection of a large number of separate fibres, whose combined contraction gives motion to the whole.

But the muscle is not always itself fixed to the bone which it is to move. It often terminates in a tendon, or sinew, which is attached to the bone in its place, acting like a cord upon which the muscle pulls. Thus muscles are capable of producing motion at a distance from themselves. The advantage of this is seen in the hand. The purposes of this organ demand a great variety of delicate motions, as well as a good deal of strength. Hence there is required a large quantity of muscular flesh. Were this placed on the fingers, which are to be moved, it would render them clumsy and cumbersome. Instead, it is nearly all disposed upon the arm, between the elbow and the wrist, and the requisite power is transmitted to the hand by long tendons. These produce the motions without interfering with the delicacy of the instrument in which they take place.

The size and shape of the trunk and limbs is dependent a good deal upon the muscles lying upon them, except when they are covered by large quantities of fat. The relative strength of the different parts of the body is determined by their relative quantity of muscle. The development of the neck of the ox, the neck and fore limbs of the lion, the hind limbs of the kangaroo, the legs of the ostrich, are indicative of a peculiar power in those parts, and they show that these animals have occasion for peculiar use of them. In the same way, men of a particular physical formation may be qualified for one occupation rather than another. On the other hand, occupations calling for the use of the muscles of particular parts bring about a greater development of those muscles. A man always working as a blacksmith or as an oarsman will have broad shoulders and large brawny arms. Artisans who use exclusively one arm will have that arm larger than the other. Hence occupations that require severe bodily labor usually produce some degree of awkwardness in figure and motion. The occupations of the richer classes exercise the muscles of different parts more equally. Thus the due proportion is maintained between them, and the beauty of the figure preserved. Hence, as physical qualities are hereditary, the higher classes in many countries are a more beautiful race than the lower, who have been confined for many generations to extreme labor. This is especially seen in the size and delicacy of the hands and feet.

The power of contraction is an inherent property of muscle. This may be called into exercise in various ways. Where it is laid bare in a living animal, contraction is produced by pricking it with a pin, pouring any sharp liquid upon it, or by an electric shock. Even for some time after death it retains this sensibility to the same stimulants; in Birds for a longer time than in Mammalia, and in Reptiles longer than in either. This is shown by the apparently voluntary motions observed in the common fowl after decapitation; tortoises will live and move about a long time after their brains have been destroyed and their hearts cut out.

But the natural exciter of the contraction of muscles is that furnished by the brain and nerves under the direction of the will, so far at least as voluntary motion is concerned. The brain furnishes the power, the nerve transmits it to the muscle, and the muscle then contracts in accordance with the direction of the will. The vigor of the motion will depend partly upon the power of the muscle, and partly upon the energy of the will. Thus a weak man under strong mental excitement, as in a violent passion, may make greater exertions of power than a stronger man in a lazy, indifferent state of mind.

Quickness is not always connected with strength of motion, though they may be united. It depends more upon the influence of the will, and is consequently more capable of development by habit.

The muscles of young animals are less firm of texture than those of older, and of less strength in proportion to their bulk. Beef and veal furnish examples of this difference. Young animals may be seriously and even permanently injured, if obliged to make great exertions of strength. Their growth may be checked, and the muscles prevented from their perfect development. Those who are engaged in the training of animals are aware of this fact. They know perfectly well that the permanent value of a horse, for example, may be injured in this way. It should be recollected that the young of our own species are as delicate, and may be as easily injured.

Still, in early life, a certain amount of exercise is as necessary to the healthy growth of the muscles as over-exercise is injurious. But it should be the exercise that requires quickness and variety of motion rather than strength. Drawing heavy loads, lifting heavy weights, are unfit for either young men or young animals. Running, jumping, and the various motions which require no weight to be lifted or carried, are better suited to their physical condition. Even those gymnastic exercises which put the moving parts violently upon the stretch may be attended with injury. Nature itself prompts the offspring of mankind, as well as that of all animals, to the kind and degree of motion which will aid in the proper development of the body at this period of life. Mere simple motion, for the sake of motion, is to them a high physical pleasure; next to taking food, the greatest in the early part of life. Colts, lambs, calves, kids, kittens, puppies, and even the whelps of the most ferocious animals, pass the greater part of their waking hours in running, jumping, and gambolling in a thousand ways.

Even after the period of infancy and childhood, during youth and sometimes in mature life, the propensity to motion merely for the sake of motion is often displayed, especially when the health is good and the mind exhilarated. It shows itself in the love of manly games, and more especially of dancing. This last has always been a mode in which mankind have delighted to display the elevation of the animal spirits, and the love of physical motion. It arises from the same disposition in man with jumping, running, &c., among animals. It is exhibited in its most natural and salutary form among the rude and uncultivated, and among them often has constituted part of their religious rites. It is in fact the natural mode of expressing certain feelings. In refined society it is often perverted in its character and surrounded by circumstances which interfere with its proper purposes. But when indulged in rationally, combined with and guided by music, it is not only an elegant amusement and an absolute physical enjoyment, but may be made an element of some value in physical education.

The positions assumed by animals are maintained by the exertion of the same organs as those which produce their motions, and are therefore to be considered in connection with them. They vary according to the structure. Thus we have standing vertically upon two feet, as in man; standing horizontally or obliquely upon two feet, as in birds; standing upon four feet, as in quadrupeds; with motions corresponding to these modes of standing.

Man is the only animal which stands vertically on two feet. It is a position which requires the exertion of a large proportion of the muscles of the body; and although performed by us with ease and without apparent effort, we are very slow in learning it in infancy, and it is in itself a nicer feat of balancing than many which call forth our wonder at public exhibitions. It is more fatiguing than walking, because the muscles which maintain the posture are kept constantly contracted and have no period of rest, whilst in walking the labor is thrown alternately upon different sets of them.

Standing obliquely on two feet, as in birds, has been sufficiently explained in treating of their peculiar structure. Standing on four feet requires less skill and less strength than on two. Hence many quadrupeds are able to stand and walk at birth; for, although their feet are smaller than those of man, they form altogether a larger base to rest upon. Hence, too, they can sleep in this position, and maintain it much longer without fatigue. We have, however, one mechanical advantage, which is in them compensated by a mechanical provision. Our heads, which are quite heavy, are balanced upon the end of the spine by a very nice adjustment of muscles whose office is best illustrated by the effects which follow the loss of control over them, as in drowsiness and drunkenness. But the heavy head of a quadruped at the end of its neck has no similar advantage; it must mainly depend for its support upon the mere strength of its muscles acting at a great mechanical disadvantage. They must therefore be much stronger than in man. They are also aided by an elastic ligament or band, which proceeds from the bones of the neck and back, and is fixed to the head. The strength of this is proportioned to the weight of the head. Thus in the elephant it is very large; and in the mole, which uses its head to support and move great weights of earth, it is bony.

There are three modes of progression common to animals,—walking, leaping, and running. In walking the body is always sustained upon the earth by at least one of its extremities. In leaping it is raised entirely up and projected through the air. Running partakes of the character of both. It consists like walking in a continued succession of steps, but resembles leaping in the circumstance that at each step the body is raised from the earth, and consequently it is a succession of leaps. In leaping the muscles make a quicker and more powerful contraction than in walking, and hence it is more fatiguing. A horse when walking can draw a heavy load for many hours, day after day, with little exhaustion; but upon the run he can go but a few hours and carry but a light burden.

In walking slowly and deliberately upon two feet, the weight of the body is thrown alternately upon each, the centre of gravity passing successively from one to the other. There is thus a lateral motion at each step. But when the pace is rapid, especially in a vigorous person who has no ungainly habits of motion, the body is not balanced successively upon each foot, and the centre of gravity does not pass entirely from one to the other, but remains between the two, moving forward in a line more or less direct. There is consequently but little lateral oscillation, and the feet are kept near one another. But in young children, in the aged, and in the weak, it is difficult to maintain the balance under these circumstances; the centre of gravity is liable to pass to one side or the other, out of the line of motion, and the person to fall. To obviate this the legs are spread apart, the base upon which the body rests is thus enlarged, and the balance more easily preserved.

When from any cause of muscular weakness a difficulty exists in keeping the balance, it is rendered easier by quickening the motion, throwing the weight rapidly from one foot to the other, and thus preventing the centre of gravity from falling upon either side in the interval between the steps. These circumstances explain the peculiar gait of invalids, infants, and the aged. It is easier to keep the balance in walking than in standing, and in running than in walking. Hence the drunkard can run when he can neither stand nor walk without falling. Hence, also, it is easier to run than to walk upon a narrow pathway or upon the ice.

The motions of the horse combine most of those of which four-footed animals are capable. In his walk the body is pushed forward by the hind limbs, and one of the fore feet, suppose the right, is at the same moment lifted up. To this succeeds almost instantaneously the left hind foot. They are then placed upon the ground in the same succession, the left hind foot just behind the left fore foot. The two other feet go on in the same order, the whole striking the ground with a measured beat, easily distinguishable, namely, two sounds very near together, a longer interval, and then two more like the first two. In this movement the hind feet would interfere with the fore feet were the steps long; but this is not the case, and the horse is consequently a slow walker, and when taught to mend his pace, it is not by taking longer steps, but by taking them more rapidly.

In the trot one of the fore feet and the hind foot of the opposite side are lifted from and placed upon the ground together, and the body is thrown forward by the two remaining feet, with so brisk a motion that it is lifted entirely from the earth and projected forward, the four feet being all in the air at once. This circumstance enables the animal to move so rapidly with this pace, because the hind feet may thus fall into the track of the fore feet, or even pass beyond them.

This diagonal motion is the most natural and seems the easiest to the quadruped. Both sides are equally supported, and little effort is required to balance the body.

In the full gallop both the fore feet are raised at once, and the body is thrown forward with a leap by the two hind feet. In the canter, or half gallop, the motion differs in different animals; the feet not being raised or falling together, but at intervals. Sometimes the two front feet vary whilst those in the rear fall together; and sometimes each of the fore and hind feet falls at distinct intervals.

In the amble, or pace, the two feet of the same side are moved together instead of the diagonal ones, so that both are on the ground at once, and the body is carried forward with a sort of rotary motion. The pace may consist like the trot in a succession of leaps, or it may be a mode of the walk. In the latter case, as there is no danger of the hind feet interfering with the fore feet, as in the common walk, the steps may be made much longer and the animal consequently move at a more rapid rate.

The rack differs from the pace merely in the circumstance that the feet of the same side are lifted and put down in quick succession, instead of together. The hind foot is first in order, and the fore foot of the same side succeeds it at a very short interval. This is sometimes quite a rapid movement and very easy to the rider, since there is none of that jolting which accompanies the trot and gallop, but simply an agreeable vibratory motion.

In the horse the principal impulse forward is given by the hind feet, the fore feet being thrown forward to support the body when it descends. This is especially observed in the gallop. In some animals, whose hind limbs are much the stronger and longer, this is their principal mode of progression when moving with rapidity, as in the squirrel and rabbit. In some, as in the kangaroo, the disparity is so great that their movements are chiefly effected by very long leaps. In a few cases, as in the camelopard and the sloth, the fore limbs are disproportionately developed, and then the body seems to be dragged forward mainly by them. This in some measure is the case with the monkey tribe, by whom the act of climbing is performed more by the anterior than the posterior limbs.

Where the power of the four limbs is pretty equally divided, the trot is the most natural form of running, though some of the smaller animals prefer the gallop. With many species the amble is the common pace. This is the case with some animals of the cat kind, as the lion, and some of the ruminants, the camelopard, the camel, the dromedary, and the llama.

These motions are performed upon a solid, resisting basis, but flying and swimming take place in a yielding medium. In the former case the whole force exerted is made to bear on the body of the animal; but in the latter a part is lost by the giving way of the air or water, just as when a man springs from a very small boat he must make some allowance for its backward motion if he wish to reach a certain point.

When a bird wishes to fly, it begins either by a spring into the air from the earth or from some eminence. On the ground, those with short legs and large wings find it somewhat difficult to rise. A bird, as soon as it is in the air, raises its wings in a state of partial extension, and then, expanding them fully, brings them down with a smart stroke, which gives an impulse forward and upward. They are then rapidly raised and brought down by repeated strokes, and the structure and insertion of the large feathers are such that they strike the air in falling with a larger surface than in rising.

The flight of birds, especially in rising, is modified by the degree of obliquity at which the wings act. In some, their stroke is almost directly downward, so that they can rise directly upward. Usually, however, especially in those with long wings, the impulse is given obliquely backward, so that they can only ascend obliquely. Some of the larger birds of prey, as the eagle, falcon, and hawk, find it difficult on this account to rise rapidly from the ground, except by flying against the wind. This corrects the too great tendency to horizontal motion. A hawk, in rising from a low and sheltered piece of ground, will be often observed to fly near the surface of the earth for some distance, rising slowly till it meets the wind, when the ascent becomes more rapid.

Swimming, in fish, is mainly produced by the action of the tail fin, the others being chiefly instrumental in balancing the body, equalizing its motion, and probably also in aiding to ascend and descend. Fishes leap by bending their bodies and then extending them suddenly, the impulse being thus given from the side of the body as well as the fin. In this way they will rise into the air many times their length, sometimes in sport, sometimes to escape pursuit, and sometimes to ascend a rapid or fall.

There are various other particulars connected with the motions of animals which are worthy of notice. The dromedary has been mentioned as among the swiftest of quadrupeds; at any rate it is so for any long distance. For a short course, perhaps, it is equalled by the horse. The famous racer Eclipse went at the rate of nearly a mile in a minute and a half, and the still more remarkable one, Flying Childers, at the rate of nearly a mile in a minute. These distances were accomplished on the full gallop. The best trotters have made a mile in about two minutes and a third; but the trot can be continued for a longer time than the gallop. One of the most remarkable feats both for speed and endurance is recorded of an English postmaster, who rode two hundred and fifteen miles in eleven hours, employing twenty-one horses. This was at the rate of nearly nineteen miles an hour, each horse being driven ten miles and a quarter at this speed, or a mile in three and one fifth minutes. The reindeer is little inferior to the dromedary in speed or endurance. On an emergency, it will travel with its sledge nearly one hundred miles for a single day; and from sixty to seventy, for several days in succession. A fox, when hunted, will run before the hound and horse for fifty miles, at a rate which wearies both, and has not unfrequently killed the latter. The speed of the hare is nearly as great.

It is true of leaping as well as of running, that the performances of small animals exceed those of the larger in proportion to their size. Thus the kangaroo, a tolerably large animal, weighing about as much as a sheep, can leap about twenty feet, between three and four times its length, whilst the jerboa, a native of Canada, a very small animal, leaps fifty times its length. This seems at first very remarkable, yet it is in strict accordance with the laws of mechanics. The objects of this are pretty clear. It gives the smaller species a fair chance of escaping from the larger; besides, as the texture of their parts does not increase in strength and power of resistance in proportion to their size, the larger animals would be destroyed by the concussion, were they capable of exertions proportioned to those of the smaller. For the same reason, small animals can fall a much greater distance than the larger in proportion to their size; indeed, absolutely a much greater distance. A mouse, a squirrel, or a cat may fall fifteen or twenty feet and escape without harm, whilst a horse, an ox, or an elephant would be irreparably maimed.

Birds have at once great disposition and great power for motion. The ostrich, in whom the amount of muscle, which in other birds is appropriated to the movements of the wings, is transferred to the legs, is the most rapid of all animals on foot, easily distancing the fleetest Arabian horses. But it is in the flight of birds that we find the most wonderful exhibitions of speed. The common crow can accomplish twenty-five miles an hour, but it is one of the slowest of birds. The flight of the eider-duck has been found to average ninety miles, the swallow a little more, but the swift two hundred and seventy; and these birds will pass the greater part of the daylight upon the wing. Hawks fly at the rate of one hundred and fifty miles, and eagles not much, if any, less. Several facts are historically recorded, which show that these estimates are not probably exaggerated. A falcon, belonging to Henry IV. of France, escaped from Fontainebleau, and was found, twenty-four hours afterward, at Malta, one thousand three hundred and fifty miles distant. This would give fifty-seven miles an hour, supposing it to have been all the time upon the wing; which is not likely, so that its speed was not probably less than from seventy-five to one hundred miles while in motion. A canary bird has been known to fly from Andalusia to the island of Teneriffe in sixteen hours, the distance being about eight hundred miles. Birds have been killed in the northern States of the Union, in whose crops was found rice undigested which must have been eaten in the rice-fields of Carolina.

Of the rate at which the swimming Mammalia and Fishes move, we know much less. It is greater than that of quadrupeds, but less than that of birds. Boats and sailing vessels rarely exceed ten or twelve miles an hour, but whales and porpoises pass by them when under full sail with apparent ease. There is reason to believe that true fishes move more rapidly than this. The speed of a whale is probably not less than twenty miles an hour, and the fish which migrate in shoals go at least as rapidly.

Some animals possess a capacity for motion dependent upon a power of suction that enables them to attach themselves closely to objects upon which or over which they wish to move. Many insects are able, probably by this provision, to walk along perpendicular walls, or even the ceilings of rooms, as the common house-fly. A structure for this purpose has been supposed to exist in the walrus and seal, by means of which they are able to crawl up the sides of smooth rocks or pieces of ice, and also to make an opening from beneath upward, through an expanse of ice.

A species of lizard in the East moves about like an insect, and adheres to perpendicular and inverted surfaces with great tenacity. Its feet have been found provided with a great number of cavities, which act like cupping-glasses and fit them to the smoothest surfaces. A kind of fish, called the remora, has upon the top of its head a large surface endowed with this power. Being naturally of a slow and indolent habit, it thus attaches itself to the bodies of other fish, or to the bottoms of vessels, and is thus transported from place to place. So aware is it of its necessities that, when once attached, it cannot be induced by the most tempting bait to quit its hold till the end of its journey. It was an ancient belief that this fish had the power of impeding or even arresting the progress of the vessel to which it was attached, and to this was once attributed the loss of the battle of Actium.

There is no class of animals which present the phenomena of motion in so varied and remarkable a manner as Insects. They, indeed, combine the powers of all the other classes, sometimes even in the same individual at different stages of its existence. They walk, run, jump, and burrow with the quadruped. They fly with the bird. They glide or crawl with the serpent. They swim with the fish. The locust by the help of its wings leaps two hundred times its own length, and the flea without them a corresponding distance. The froghopper exceeds this by one quarter, leaping two hundred and fifty times its length. There is a kind of spider which spins no web to entangle its prey, but secures it by leaping upon it, which it can do even sideways. It has been seen to jump two feet upon a humblebee.

Their rapidity of motion in flight is not less remarkable, and some species can fly in all directions without turning. Leuwenhoek once watched a swallow chasing an insect in an inclosure a hundred feet long. The little creature flew with such astonishing velocity, to the right, to the left, upward, and downward, that the bird, remarkable not only for the rapidity of its flight but the quickness of its evolutions, was foiled in all its attempts to seize it. Many insects that live but for a short time in the winged state, pass almost the whole of this period upon the wing. It has been calculated that, in its ordinary flight, the house-fly makes six hundred strokes with its wings which carry it five feet in the second; but when alarmed its velocity is so increased, that it has been calculated to make four thousand strokes and pass over thirty-five feet in the same time.

The rapidity and adroitness of these animals is in no way more familiarly illustrated than by observing them in a railroad car. When travelling at the rate of thirty or even forty and fifty miles an hour, they move about from place to place, backward, forward, upward, and downward, exactly as if the vehicle were at rest. Yet in this case their motions must be most nicely adapted with reference to the places on which they alight and the direction in which they fly.

The speed at which some of them run is not less worthy of notice. We are told of a fly, so minute as to be scarcely visible, which can run six inches a second, making in that time one thousand and eighty steps. They climb also in various ways and with great skill; some by claws which lay hold on irregularities in the surface of bodies, some by means of soft cushions formed of dense hairs which line the under part of their limbs, some by suction, and others by means of a tenacious fluid which enables them to adhere against the force of gravity.

Insects also swim and dive. Some of them swim by the help of broad, flat hind legs, acting like paddles; others have a fringe of hairs placed in a suitable position to answer the same purpose. Some swim or float along upon the back, whilst others skate, or run upon the surface of the water.

They burrow as the mole does, principally by the head and fore legs where substances are soft, or by the aid of the jaws where they are hard. Many species in this way provide themselves with habitations: ants in the earth, many wasps in wood, and the house cricket in mortar. They bore also in search of food, and to provide a suitable place for depositing their eggs.

Some of the motions of other classes present a striking contrast in their sluggishness and drowsiness with those observed in Insects; so much so that it is not an uncommon notion, that both the fresh and salt water mussels have not the locomotive faculty. But this is a vulgar error. It is almost unnecessary to mention that the exterior part of mussels consists of two shells hinged together, which the animals can open or shut at pleasure. Every person must likewise have observed, in the structure of the animal itself, a fleshy protuberance of a much redder color, and denser consistence, than the other parts of the body. This muscular protuberance, which consists of two lobes, has been denominated a *trunk* or *tongue;* but it is an instrument by which the creature is enabled to perform a progressive though a very slow motion; and, therefore, in describing its manner of moving, I shall call these two lobes the animal's *tentacula* or *feet.*

'When inclined to remove from its present situation, the river mussel opens its shell, thrusts out its tentacula, and, while lying on its side in a horizontal position, digs a small furrow in the sand. Into this furrow, by the operation of the same tentacula, the animal makes the shell fall, and thus brings it into a vertical position. We have now got our mussel on end; but how is he to proceed? He stretches forward his tentacula, by which he throws back the sand, lengthens the furrow, and this fulcrum enables him to proceed on his journey.'

CHAPTER V. (W.)

VOICE OF ANIMALS AND THEIR MODES OF COMMUNICATION.

As the existence of sight implies objects to be seen, the existence of hearing implies sounds to be heard. Nature is full of these. To man all of them are more or less significant, and are the objects of his attention; that of other animals is chiefly engrossed by those that serve to warn them of danger, to direct them to their food, or to establish an intercourse with others of their own species.

Voice, in its proper sense, is confined to those animals that breathe air through a windpipe by means of lungs. Hence it belongs only to the vertebral animals of the first three classes, Mammalia, Birds, and Reptiles. The air entering the lungs for the purposes of respiration is, in its passage, — chiefly in expiration, — made to vibrate by an apparatus provided for the purpose, which gives origin to sound. This apparatus, called the larynx, is, in man and quadrupeds, placed at the top of the windpipe. In birds it is situated lower down, where the canal divides to pass to the lungs. The structure of these organs is too complicated to be made intelligible in all their details without actual inspection of the parts themselves. It is sufficient here to say that the *principle* upon which vibration takes place is the same as that upon which it depends in some wind-instruments, as the hautboy and the clarinet, but modified so as to produce variations far more delicate.

The possession of voice does not imply the use of words, but independently of words, it is still capable of conveying a great variety of information from one individual to another. By mere voice, without articulation, animals express their wants, their pleasures, their passions, and their affections; and this is, in some measure, the case even in our own species. But in man the power of articulation, or the utterance of words, adds almost indefinitely to its capacity. Articulation does not depend upon the same organs as voice. It consists in a modification which voice receives as it passes through the mouth, throat, and nose.

Articulation embraces two distinct kinds of sound, the vowel and consonant. In the former the sound is continuous, and its character is derived from the form assumed by certain parts of the mouth and its neighborhood, through which the air passes. In consonants, there is a more or less complete interruption of the current of air. Every one can determine this difference by experiment in his own person. The real distinction between vowels and consonants, however, is not so strongly marked as is usually represented. Although when a vowel sound is uttered it may be in a certain sense indefinitely prolonged, yet the peculiarity of the sound is confined to its commencement, and has in it something of the character of the consonant, of which the prolongation is destitute. Thus the prolonged sounds of *a*, *e*, and *i* are alike, and those of *o* and *u* but a little if at all different; whilst some consonants, as *s* and *l*, are quite as capable of prolongation. These points, however, though sufficiently curious and interesting, do not come within the plan of this work.

A few birds can imitate human articulation, as explained in another chapter, but, so far as we are able to distinguish, the voice of most animals chiefly consists in the production of the vowel sounds. Still there is in some quadrupeds an imperfect approach to the production of consonants, as of *n* in the horse, *m* in the cow and cat, *b* in the dog, and *q* in the hog. In birds, and in some reptiles, there is a nearer approach to the articulation of consonants, as in the parrot, the bobolink, the whippoorwill, and the frog. Probably there are many modifications of voice among animals which we do not recognize, but which convey distinct information from one to another of the same species.

In the chapter on the Artifices of Animals will be found an account of the operations and manners of monkeys, which seem to imply the possession of a language capable of conveying a considerable variety of ideas and expressing a variety of emotions and passions. That it is totally unintelligible to us, and that it appears like an inarticulate chattering, is no certain proof that it actually is so; since the same is true of the rapid talking of persons in an unknown tongue, and especially of that of the more barbarous and uncultivated savages, like those of Australia and Van Diemen's land. Had we the same aid, by means of a common nature, of analyzing the sounds uttered by monkeys that we have with regard to savages, we might perhaps attain to a knowledge of the precise character of the language they employ, and find that it has, at least, some approach to an articulation like that of man.

Among the invertebral animals, the principal examples of the production of sound exist among insects. In them it is not effected by the organs of respiration, but by means simply mechanical. There are many sounds produced by them which have no purpose corresponding to that of voice as a means of communication, but are purely accidental. Such are the humming and buzzing produced by their wings, and the noise made by large armies of locusts when feeding, which has been compared to the crackling of flames driven by the wind. But there are other sounds, apparently intended to answer a distinct purpose, although we cannot always understand what that purpose is. Such are the humming and singing sounds of gnats, flies, mosquitos, bees, &c. These are not always, if ever, produced by the mere vibration of the wings, but by that of a membranous plate situated upon the chest, which seems intended for this purpose only. The vibrations are not occasioned by the passage of air, but by the muscular contractions of the insect, which, it has been calculated, occur three thousand times in the minute. The hum of bees varies with the circumstances under which it is made, being sometimes angry, sometimes plaintive, and sometimes joyous. The queen produces peculiar sounds, which are taken note of by the rest of the swarm and govern their motions.

Among the most noisy of insects are the cricket and some of the tribe of grasshoppers. One of these, popularly called a locust, is remarkable for the loudness and shrillness of its note, in which it will sometimes persevere for a long time. It is usually heard in very warm summer days. In Brazil there is a species which it is said may be heard at a mile's distance. The sound in some of them is made by the rubbing of the covers of their wings upon each other, and in some by the vibrations of a horny drum or membrane. Some of the luminous insects have also this power, especially the great lantern-fly of Guiana, which disturbs the night by sounds resembling that of a razor-grinder. Among the white ants, the neuters or soldiers appear to direct the workers or laborers by striking some hard substance with their mandibles, which elicits a shrill, quick sound, whilst the laborers answer with one resembling a hiss. The insect called the deathwatch produces its peculiar sound in the same way.

Beside communication by sounds, it is evident that there are among animals other ways by which information is given and received. We often observe this in our domestic species, but it is still more remarkable among those in a wild state. It appears to be a language of signs, resembling, to a certain extent, that which serves for intercourse with the deaf and dumb, or more strikingly with those who are deaf and blind. It is wonderful in these last cases to notice by what very slight and almost imperceptible signs ideas are communicated, even those of a complex and abstract nature. When we reflect how very simple are the wants and ideas of animals, and how limited the range of subjects on which it is necessary for them to communicate, it is not at all incredible that there may exist a very perfect language of signs of this description among them, so minute as to be undetected by us, and yet quite intelligible to them.

The various tribes of ants furnish remarkable examples of this sort of communication. Contact seems to be necessary, as it is to the deaf and blind. "If you scatter the ruins of an ant's nest in your apartment, you will be furnished with a proof of their language. The ants will take a thousand different paths, each going by itself to increase the chance of discovery; they will meet and cross each other in all directions, and perhaps will wander long before they can find a spot convenient for their reunion. No sooner does any one discover a little chink in the floor through which it can pass below, than it returns to its companions, and, by means of certain motions of its antennæ, makes some of them comprehend what route they are to pursue to find it; sometimes even accompanying them to the spot; these, in their turn, become the guides of others, till all know which way to direct their steps."

According to Huber, this intercourse is partly maintained by striking the head against the corselet, and by the contact of the mandibles, but chiefly by means of the antennæ. These organs are, no doubt, possessed of a very delicate sensibility, and are not only the seat of the senses of hearing and touch, but may have other capacities of perception of a nature unknown to us. They appear to be closely connected with the instinct of the animal, and to be the medium through which chiefly it receives impressions from without. Ants frequently use them on the field of battle to intimate approaching danger, and to recognize those of their own party when mingled with the enemy. In the internal economy of their dwellings, they are employed to give notice, to those who have the care of the larvæ, of the presence of the sun, exposure to which is so necessary to their development; in their excursions and emigrations, to indicate their route; and in all their various enterprises, to give information as to the time of departure, the order of march, &c. Ants lay up no store of provisions, but depend upon daily supplies; those laborers, therefore, that remain at home, rely upon parties foraging abroad for their regular sustenance. Sometimes this is in the form of small insects or other substances which are brought into the nest. But when the articles of food found are too bulky to be directly conveyed there, the ants fill themselves with their juices, and, on their return, disgorge them for the benefit of those whose labors prevent them from going abroad. The hungry animal begins by striking with both its antennæ, very rapidly, the antennæ of the one from whom it waits its supply. It then draws closer, with its mouth open, and its tongue extended to receive the fluid which may be observed to pass from one to the other. During this operation, the recipient does not cease to caress its benefactor with its antennæ and with its fore feet.

The nature of the information conveyed on these different occasions cannot even be imagined. The communication is not made by any visible gestures, but simply by the contact of the parts. This, indeed, is rendered necessary by the fact that such communication is often required in the total darkness of the interior of the hill. Hence, too, it happens that an ant can only be understood by a single one of its companions at the same time, but the information it conveys passes from one to the others with extreme rapidity.

The means by which bees communicate with each other, and the instrumentality by which information upon important points of their internal arrangements is communicated with inconceivable rapidity to all parts of the hive, are probably of the same general character.

In one of the lakes in Ceylon, it is the belief of the fishermen who frequent its waters, that musical sounds are heard to proceed from a certain spot, resembling the faint sweet notes of the Æolian harp. Sir Emerson Tennent satisfied himself by a visit to the place that this was actually the fact. "They came up from the water like the gentle thrills of a musical chord, or the faint vibrations of a wineglass when its rim is rubbed by a wet finger. It was not one sustained note, but a multitude of tiny sounds, each clear and distinct in itself; the sweetest treble mingling with the lowest bass. On applying the ear to the woodwork of the boat, the vibration was greatly increased by conduction." The last-mentioned fact seems to imply that the sounds were actually produced in the water, and not in the air. Similar sounds have been heard at other places, both in the old and new continents. They have been attributed, with great appearance of probability, to some of the testaceous Mollusca. Their object, we are not sufficiently acquainted with the habits of these animals even to conjecture. That they are totally useless we have no right to assert.

Where sounds proceed from any animal by an arrangement of organs which has their production for its specific object, as in some of the cases above mentioned, it is fair to infer that they are intended to be heard in order to some definite purpose, and consequently to be heard by other animals of the same species.

So that an organ for the production of sound almost necessarily implies in the same animal an organ by which that sound is heard, or at least perceived and appreciated. This is not true of those cases in which the sound is the mere mechanical result of the action of organs in the performance of an ordinary function. Thus the buzz of the common house-fly is a necessary result of the rapid beating of the air by its wings, and does not imply the sense of hearing, though it may coexist with it; but the sounds of the katydid, of the cricket, and those of the bee, as emitted for an obvious purpose, do imply the existence of such a sense.

It is not improbable that the power of appreciating sounds, either by a distinct organ for this purpose, or else by some organ which has also another function, as the antennæ in insects, is more widely diffused among the lower animals than we are accustomed to imagine. The more minutely researches are carried among such animals, the more perfect and varied is their organization found to be; and it would not be surprising if light and sound were found to be as generally perceived, in some degree at least, as taste and odor.

Some of the prevision which insects evidently possess of changes of weather may be due, in part at least, to an exquisite sense of hearing, that receives impression from the motion of agents which usually produce no impression upon us. Thus all ordinary changes of weather are preceded and accompanied by changes in the electrical condition of the atmosphere. This necessarily produces currents of electricity. Now we can ourselves hear these currents when of a certain volume or intensity, as in thunder and lightning, the discharge of an electric battery, and even the milder flow of the aurora, or from a fully charged Leyden jar. To a finer sense, the flow and turmoil of this subtiler fluid may be as obvious as that of the atmospheric air is to us, and thus inform the animals who possess it of changes and conditions of which we are insensible. Of the possibility of such a difference in the delicacy of hearing we are informed by the singular fact that certain very sharp sounds, perfectly audible to some persons, are never perceived by others.

CHAPTER VI. (W.)

OF SENSATION IN GENERAL. — FEELING AND TOUCH. — TASTE. — SMELL.

The connection between the animal and the external world is maintained by means of the several senses.

Whatever may be its natural desires and wants, these are necessary in order to their gratification. Their number and degree of perfection will correspond to the necessities and the situation of each individual. The animal which does not voluntarily seek its food needs not sight; the animal which cannot fly when pursued needs not to hear. There is the same harmony of relation between the senses and the powers called into action by them, that has already been pointed out between other circumstances in the structure of animals and the condition in which they have been placed. None have appetites or wants which there is not a provision for their indulging, and indulging with a certain degree of safety. There is always a correspondence, for example, between the appetite that suggests a particular kind of food, the senses that perceive it, the limbs which procure it, and the organs by which it is digested.

It makes no difference as to the number and perfection of the senses required, whether the presiding principle with which they are connected be intelligence or instinct. It has been argued that the wonderful operations brought about by certain animals, insects particularly, are not to be attributed chiefly to instinct, because, were they owing to a principle so mechanical, they would not require organs of sense so delicate as those they possess. "If," says a writer on this subject, "insects in all their actions were directed mainly by their instinct, they might do as well without sight, hearing, smell, and touch." It might as well be urged that they could do without limbs, antennæ, mouth, and other external organs. But in truth the nature of the internal principle has nothing to do with that of the organs by which it is administered. It makes no difference in the bee, for example, whether it be induced to build its cell and provide its food by a blind instinct or a reasoning intelligence, so far as the organs by which it acts are concerned. In either case it requires organs of taste to perceive, as well as organs of motion to procure, the necessary materials; organs of touch to take note of the progress of its work as it goes on, as well as organs of motion to carry it on. The number and degree of perfection of the external senses are always strictly in proportion to the wants and desires of the internal governing principle, whatever that may be.

No animal possesses more than the five senses of sight, hearing, smell, taste, and touch; many are deficient in some of them, but none in all; and we may be sure that every one possesses all that are essential to the condition of existence in which it has been created.

In the lowest of the Radiata it is probable that there exists only a vague and indistinct perception of the qualities of external objects. Their senses may be resolved into a certain degree of feeling, or touch. We can hardly attribute to them either of the others distinctly, yet this one sense appears to be so modified as to be capable of performing some of the offices of the others. Their feelers or tentacula, for example, can determine whether the object which they encounter in the water is fit for their food. Touch them with a stick or the finger, and they shrink from it. Let them be touched by a worm, and they immediately grasp it and convey it to the mouth. This implies something of the attributes of smell and taste. So, too, they are influenced by light, and by those vibrations which constitute sound; and thus in a certain limited way they are influenced by the causes which excite all the senses. We cannot say that they have smell, taste, hearing, or sight, yet the sense of feeling is so modified as to perform, as far as it is needed, the office of them all.

As we ascend in the scale of being, the senses of smell and taste become more distinct from that of feeling, but it is not till we arrive at the highest species among the Articulata and Mollusca that we find them entirely distinct. Here, too, we first perceive the existence of the superior senses of sight and hearing. It is to be remarked that these, which furnish the only very distinct information concerning objects with which animals are not in contact, are usually accompanied by a considerable capacity for motion from place to place. It is true that smell, also, may give information relating to bodies not in contact; but this information is not of a very exact nature, and does not relate to objects at any considerable distance, except in those species which possess also sight and hearing.

In some of the Mollusca, the snail for example, a rude organ of sight is detected. Hearing is probably also present, but as from the nature of the vibrations on which it depends, an external organ is not necessary for its exercise, we cannot point out its seat. In the cuttle-fish the organs of these two senses become more distinct, and they are accordingly capable of free and rapid motion from place to place.

In Insects there are found increased and varied powers of motion, accompanying increased powers of sense. But with partial exceptions it is only in the vertebral animals that all the senses are found exercised by organs of determinate place and structure.

Every part of every animal which is organized is capable, under some circumstances, of being influenced by the contact of external bodies. This general sense of feeling resides in every part, but it is only when exercised by particular organs, and in a peculiar way, that we give it the name of touch. An animal may live, and exercise its necessary functions, with this sense only. This is not true of any other. No animal can do it by means of any other single sense.

But although every part feels in this general way, the skin, in the higher animals at least, is the organ in which the sense especially resides. That modification of it which we call touch is still more limited in extent, whilst the information it gives is far more definite. Feeling acquaints us merely with the presence of bodies; by touch we acquire a knowledge of some of their qualities. Touch is the sense of feeling in an active state; and it becomes active chiefly by the form and relation of the organs in which it resides. When an external body is touched by a single plain surface, like the extended surface of one of the limbs, the cheek, or even the palm of the hand, we merely perceive its presence, its temperature, perhaps its hardness, and some other very general qualities. But when it comes in contact with two or more surfaces, as the lips, the tongue, the fingers, then some of its properties, especially its shape, regularity of surface, &c., may be perceived. The nicety of touch depends upon the number of distinct impressions which we can receive and compare together. If we touch a body in its different parts with the tip of a single finger many times, we get a less accurate idea of its figure and dimensions than when we grasp it but for a single moment with the whole hand, because the connection and relation of the impressions are of more importance than their number. This makes the hand of man the most perfect organ of touch in nature, though perhaps, for certain limited purposes, we may find its equal in some of those organs of insects by which their wonderful operations are carried on.

Next to the hand of man come those of the monkey tribe and the trunk of the elephant. In all of these is perceived the same characteristic of structure which gives its excellence to the hand of man, but in a less perfect degree.

In departing from man, we trace a gradual variation in the structure of the anterior extremity, till, in the complete quadrupeds, it becomes a mere organ of motion. Precisely in proportion as it becomes an instrument of motion, it ceases to be an organ of sense; so that the parts corresponding to those which in man are gifted with that delicate sensibility and exquisite discrimination characteristic of the human hand, in the ruminants and in the horse kind have degenerated into an insensible hoof, fit only to aid the animal in its progression. But there is in this case some compensation. In our own species, when one sense is blunted or obliterated, the others become more acute; and so in animals, in proportion as the sense of touch is lost by the diversion of their extremities to other purposes, it is either transferred to other parts, or the other senses become more acute. Man, whose touch is so nice, lacks nicety of smell and taste. The degree in which these senses are possessed is indicated by the size and structure of their organs. Hence, as they reside in the face, in man the face is small compared with the head; the nose and mouth do not project; but as we descend through the apes and the carnivora to the more complete quadrupeds, these parts do project, and the fore limbs deteriorate till we finally find them terminating in hoofs.

The only parts, in complete quadrupeds, which are possessed of a nice sense of touch, are the extremity of the nose and lips, and the tongue. This is the more necessary to them because the lips answer with them the same purpose that the fore limbs of other animals do, namely, to seize their food. This relation is strikingly illustrated in some animals, where a peculiarity of structure is required. Thus the elephant, not being able to take food into his mouth by his lips, has their nice sensibility carried out to the extremity of the trunk, where, as in the nose of other quadrupeds, the senses of smelling and touch are united just where their united function is required.

One of the most singular exercises of sensibility is that which has been noticed in the bat, when deprived of its sight, even by the entire destruction of its eyes. Spallanzani, observed that when some of these animals were confined in rooms opening into each other, they continued to pass through the door, while on the wing, with the same facility as when possessed of sight. Suspecting this might be the result of habit, willow rods were placed perpendicularly in different parts of the rooms, and their position was from time to time changed; yet the animals still flew freely around, avoiding the ceiling, the walls, the door, and the rods, precisely as if they had continued the exercise of sight. It seems impossible to attribute this singular phenomenon to anything but an exquisite sense of feeling, probably existing in the extended membrane of the wings.

In Birds, Reptiles, and Fishes, the sense of touch is very confined, as is obvious from the very structure of their bodies; whilst in Insects it assumes an importance but little if at all inferior to that which it has in man himself.

The sense of taste is in some respects nearly related to that of touch. Both require that the object should be brought into contact with the organ. But they are intended to inform us of qualities of a different kind; namely, touch, of the physical and mechanical; taste, of what may be called the chemical, qualities of bodies. In order to taste, it is necessary there should be a solution of the body tasted; and accordingly where this sense is very delicate, we find organs for breaking down and grinding the food, and a fluid, the saliva, which is capable of effecting at least a partial solution of it.

Taste is most perfect in those animals which chew their food thoroughly and have a fleshy tongue. It is possessed in a high degree by the Mammalia. In Birds, Reptiles, and Fishes, it is probably less delicate; and in most of them their food is swallowed without mastication, though it is sometimes broken to pieces by the mouth and teeth. In some Insects there is ground for believing that it approaches in delicacy that of man. In the lower classes its seat and the degree in which it is exercised can be only conjectured. In many it appears to be blended with the general sense of feeling, and may be diffused over the whole internal surface of the body in such a way that it accompanies digestion. The pleasure of taste is something distinct from the gratification which attends the taking of food. This last is the satisfaction of a want, and is perhaps equally pleasurable in all animals, whether taste be exercised or not.

The sensation of taste resides chiefly in the tongue, yet the parts about it essentially contribute to its distinctness and its vividness. When we exercise this sense, the substance which we wish to taste is pressed by the tongue against the roof of the mouth, and the different parts of the mouth are contracted closely around the tongue and the sapid body. The more complete and perfect the contact which thus takes place, the more perfect is the act of tasting. The internal surface of the mouth is very little capable of perceiving or distinguishing tastes, unless this pressure takes place. In fact, if the mouth be held open, and a substance of even a pretty powerful taste be applied to the tongue, the impression it gives is very indistinct and indefinite, and becomes perceptible only by closing the jaws and bringing the tongue into contact with the roof of the mouth. Hence arises the pleasure we feel in the acts of chewing and swallowing. The motion of the jaw, and the action of the teeth and tongue, mix the food with saliva, thus putting it into a fit state for producing the sensation of taste, and, at the same time, convey it between the tongue and the roof of the mouth; whilst, in swallowing, almost the whole internal surface of the mouth contracts upon and comes in contact with the morsel, raising the pleasure to the highest degree.

The sense of smell is excited by what are denominated odors. These are emanations thrown off from the surface of bodies, and by means of them this sense is exercised with regard to substances which are at a distance. The nature of odor is not perfectly understood. Probably all substances possess it in some degree, for when not perceptible in their ordinary condition, it may be developed, by pounding, friction, moisture, solution, and vaporization ; and when not distinguishable by man, it may be by some other animal. It has been supposed to depend upon the projection of indefinitely small particles from the odorous body in all directions. Some substances, after giving out odor for a length of time, lose weight, and ultimately become inodorous. Some other substances, on the contrary, of which musk is a remarkable example, give out odor for many years, and even impart to other bodies the same power, and yet lose no weight, nor in any perceptible degree their odorous property. In this latter case it is difficult to adopt the usual explanation, or to conceive of so very minute a subdivision of matter as it implies ; whilst in the former it is easy to perceive that the loss of weight may be owing to changes in the condition of the body quite independent of the emanation of odorous particles, — such for example, as the dissolving in the atmosphere of essential oils. A satisfactory explanation of the nature of odor is, then, yet wanting.

Some substances act upon the organ by immediate contact: such are gases, vapors, and solid bodies in a state of fine powder. But strictly speaking this is not the pure exercise of the sense of smell. In such cases there is an actual irritation of the organ, in addition to the impression of odor. Thus the smell of sulphur is perceived when its fumes are drawn into the nostrils, but beside this impression, a smarting and acrid sensation is produced, quite distinct in its character. So in the use of snuff, beside the smell of tobacco, there is an irritation of the organ which produces sneezing and a discharge of fluid ; neither of which takes place from the simple exercise of smell.

This sense is in such constant exercise, that we are hardly aware how singular and curious are many of the phenomena connected with it. That a slight flower should be able in a few moments to fill a large room with its fragrance, and yet lose none of its weight; that an essential oil should communicate to the vessel which contains it a power of producing odor that can only be destroyed with the vessel itself; that a grain of musk should communicate to large volumes of air, and to any other substances with which it is in contact, qualities which no chemistry can detect, and which are yet at once appreciated by the organ of smell,—are facts as wonderful as they are inexplicable. It almost seems in these cases as if odor were sent out, as light is from luminous, and vibrations from sounding bodies, without any loss of substance on the part of the body emitting it.

The smell and taste are the natural guardians of the appetite, and by means of them animals are for the most part directed in their choice of food. In his uncivilized state, man is also capable of deriving from them some aid; but in the ordinary condition of human society, these senses, accustomed to a great variety of unnatural applications, are seldom consulted for this purpose, and many things which are agreeable to them are injurious as food.

In animals which breathe air, the smell resides in cavities through which the air passes in going to the lungs. These cavities are placed in, around, and above the nose. They are lined with a very sensible and delicate membrane always kept moistened by a peculiar fluid, and the odorous principle, whatever it is, produces its impression by coming in contact with it. Within these cavities are bony bodies of a spongy texture, over which, and into the interstices of which, the same membrane is extended, in order to increase the surface upon which the impression is made, and thus increase the delicacy of the sense. Accordingly the degree in which animals possess it will correspond to the size and fulness of the nose and upper jaw. In animals which do not breathe air but water, the apparatus is different; the odors, being conveyed by water, are simply received into a cavity lined by a peculiar membrane, and here the sense must differ very little from that of a refined taste.

CHAPTER VII. (W.)

HEARING.

Sound is produced by vibrations in the air, or in any body capable of communicating them to an organ of hearing. There is nothing peculiar in these vibrations. They can even be seen and felt, as in the strings of a piano-forte. Hence even in animals which have no proper organ of hearing, sounds may be imperfectly perceived by the common sense of feeling.

If these vibrations are less than thirty-two in a second, although they may be seen and felt, they do not produce the impression of sound on the human ear, although they perhaps may on that of some animals. All vibrations exceeding thirty-two in a second are productive of sound, and its pitch becomes higher or sharper in proportion to their number. We commonly speak and judge of sound as transmitted through air, because it comes chiefly to us in this way; but probably all substances are capable of propagating it in various degrees of perfection and velocity. Its amount or volume is greater when conveyed through iron, stone, glass, wood, and water, than when through air; but its delicate qualities and variations are better conveyed through the latter.

Sound travels through air at the average rate of 1130 feet in a second, or a mile in about four and a half seconds. But this is liable to variations. In summer, by some accurate observations, the velocity was found to increase to 1164 feet, and in winter to diminish to 1099 feet. Upon some sultry plains within the tropics the rate was found to be 1175 feet, and upon the mountains of Quito 1120 feet. Hence it is to be inferred that heat increases and cold diminishes the speed at which sound travels; but these variations have been found to depend in part, also, upon the pressure and moisture of the atmosphere. Other circumstances, such as the force and rapidity of the wind, are also causes of variation. It thus appears that the velocity of sound is seldom exactly the same at different times, or in different directions.

For all practical purposes, the average of 1130 feet may be regarded as sufficiently near the truth.

Great variations in its velocity have been observed when it is transmitted through other bodies, and it is found to bear a certain relation to their elasticity and density. Carbonic acid gas gives the lowest known rate, — 902 feet to the second; crown glass the highest, — 17,700 or about fifteen times that of the atmosphere. Cast-iron and common glass have a rate nearly the same; the metals, wood, and tobacco pipes, from a quarter to a half less; liquids, as water, alcohol, and mercury, about two thirds less, or nearly 5000 feet; whilst the gases, with the exception of carbonic acid gas, give the same result as common air. Most of these results are given from calculation; but to a considerable extent they have been confirmed by experiment. In respect to cast-iron they were tested by an eminent French philosopher in the following manner. A series of cast-iron pipes was taken of half a mile in length, and a bell sounded in the air by its tongue, whilst at the same instant it was made to come in contact with the iron. By a person placed at the other extremity two sounds were perceived, one at the expiration of a quarter of a second, the other of two seconds and three quarters. This gives in cast-iron a velocity about eleven times that in air.

A minute sound will be transmitted to a much greater distance through a solid substance than through the air. A slight tap or scratch at one end of a piece of timber may be heard by the ear applied in contact at the other end, at a distance of thirty or forty feet, while in the air it is inaudible at two or three feet. This is mainly, however, owing to the fact that sound produced in the air is propagated in all directions, and its force is thus exhausted by its diffusion; whilst in the solid body it is wholly confined within its limits. If, however, sound be transmitted through a small and confined column of air, as in a common speaking-tube, this diffusion is avoided, and it may be conveyed to as great a distance, as through solid bodies and with more accuracy.

It is a fact important to the explanation of the sense of hearing, that sound is most readily propagated through that medium in which it has originated, and that it passes with more or less difficulty into another. Thus if two stones are struck together under water, their sound is heard at but a very short distance by a person in the air; but if his head be also placed under water, it becomes audible at a much greater distance. On the other hand, if the ear be in the water and the sound produced in the air, it is scarcely heard at all, or at but a very short distance. This is owing to the difficulty with which the vibrations pass from air into water and from water into air.

The perception of sound informs us that some change is taking place in the objects around us. The most simple office of the sense of hearing, then, is to arouse the attention; it is a warning to the exercise of the other senses, particularly that of sight. Hence the ear is always open to impressions, and is not capable of being closed against sound, as the eye is against light. Sound is an occasional quality of bodies; shape and color are constant ones. The sight and hearing, then, are closely related, and are, in fact, complementary to each other, the one giving that sort of information which cannot be derived from the other. The ear informs an animal that an enemy or his prey is somewhere about him; the eye ranges around to detect his place and his intentions. The ear informs, warns, and suggests. The eye notices, acts upon, and follows out the information it has thus received. Either is imperfect without the other.

There is much difference among animals in the degree and kind of information they are capable of deriving from sounds. This depends partly upon the structure of the organ, but chiefly upon their powers of observation and intelligence. Thus the superiority of man, in regard to the exercise of this sense, is wholly due to his intellectual preëminence. The ear in nearly all the Mammalia is as perfect as in him. They can distinguish all the varieties of mere sound that he can, but they cannot, to the same extent with him, understand, articulate, or appreciate musical sounds. This difference is wholly due to that cultivation of the sense, for which his superior mental constitution qualifies him.

In fact, by education we can perhaps teach animals to receive by language all the ideas they are capable of entertaining in common with us. The obstacle to their comprehension of language is, not that they cannot appreciate the sounds in which it consists, but that they cannot comprehend the ideas that it conveys. We find, indeed, that they are capable of receiving and conveying information between themselves by variations of sound which are, to us, very slight and indistinct.

But there are many circumstances in the condition and residence of particular animals, which require modifications of the organ of hearing. The structure which is best adapted for hearing through air, is not best adapted for hearing through water. Fishes and lobsters, for example, have an organ which differs from that of quadrupeds and birds; whilst reptiles and the cetaceous animals require still a different modification, since they must sometimes perceive sound through air, and sometimes through water.

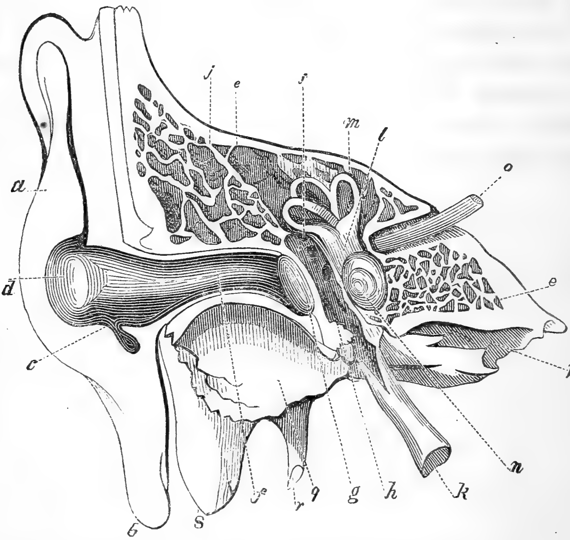
The qualities of sound which man is capable of distinguishing are five. 1. Its force, volume, or loudness. 2. Its pitch or tone with reference to the musical scale; as whether it be high or low, sharp or flat. 3. A quality designated by the French word *timbre*, for which there is no exactly equivalent English term. It embraces those differences of sound, which distinguish one musical instrument from another, as a flute from a clarinet or a violin, and which distinguish the voice of one person from another. 4. The vocal sounds, or vowels. 5. The proper articulate sounds, or consonants. The same qualities are, to a certain extent, distinguished by many animals, but in various degrees, and by none so perfectly as by man.

The organ of hearing in man is perhaps the most intricate and difficult to understand in the whole body. In many animals it is more simple; in none is it more complicated. The only part which is present in all those where an ear has been detected at all is a small sac, filled with a watery fluid, in the membranous walls of which the extreme and delicate fibrils of the nerve of hearing are distributed. This sac is generally contained in the substance of the bones of the head. The vibrations of sound produce a jar in the fluid, and this, being communicated to the nerve, is transmitted to the brain, and there produces the impression of sound. This is the essential part; but in nearly all animals there are additional ones, corresponding to the circumstances under which sound is heard, and the kind of sounds to which they are exposed. That this is so, appears from the fact that in man all the subordinate parts of the apparatus may be destroyed, and some degree of the sense be still retained, whilst if the structure of this be impaired, it is entirely lost, though all the others remain unimpaired.

In all the invertebral animals in whom an ear has been detected, this simple cavity constitutes the whole of it, and in some of the lower fishes little is detected beside it. But in man and the higher animals, it is found very complicated in its structure, and there are a number of subsidiary parts which are necessary to the perfection of the sense.

First, there is the external ear, intended to collect the vibrations

Fig. 45.



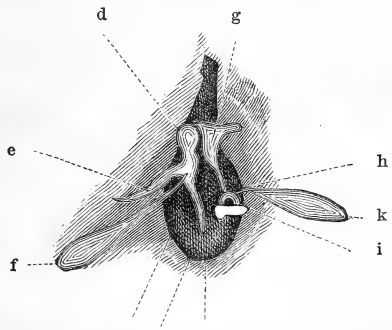
The diagram represents the external ear, the passage leading to the drum or tympanum, and the cavities of the internal ear, which is the seat of the sense. The bone in which these cavities are contained is supposed to be sawn open so as to expose them in their full extent. The internal parts are larger than in nature.

a, *b*, *c*, external ear; *d*, entrance to *f* the auditory canal; *e*, *e*, portions of bone in which the cavities are contained; *g*, membrane of the drum or tympanum; *h*, its cavity, from which the small bones have been removed; *i*, openings from the drum into *j*, cells in the bone to increase the reverberations of sound; *k*, eustachian tube leading down to the mouth and admitting air into the drum; *l*, *m*, *n*, the labyrinth, a complex cavity in the bone, containing the nervous extremities, which are the seat of the sense; into this there are two openings from the drum indicated by small black spots; *o*, nerve of hearing; *p*, canal where a large artery enters going to the brain; *q*, cavity which receives the head of the lower jawbone; *r*, *s*, projections of bone.

and thus increase their intensity. This, as common observation teaches us, varies very much in different animals. It is adapted rather to increase the volume of sound than to contribute to the discrimination of its delicate differences. From the external ear, a canal leads into a cavity hollowed out in a very solid part of the bones of the head, and called the tympanum or drum, over the entrance to which a membrane is stretched, closing it completely, like the parchment over the head of a drum. This cavity is filled only with air, and communicates by a canal — the eustachian tube — with the back part of the throat or nostrils, which admits its free ingress and egress.

On the inner wall of this cavity are two openings, leading into one still more interior, called the labyrinth. This is the essential part of the organ formerly referred to. These are also closed by membranes, whilst the cavity within is filled with the fluid by means of which the vibrations are communicated to the nervous extremities. Across the tympanum is a series of small bones, attached on the one side to the membrane of the tympanum, and

Fig. 46.



In this diagram, we are supposed to be looking outward from the internal parts of the ear into the cavity of the tympanum containing the bones in their natural position. The dark, ovoid space is the membrane, to which the arm of one of the bones is attached. These bones are called *malleus*, the hammer; *incus*, the anvil; *os orbiculare*, a small globular bone; and *stapes*, the stirrup, the oval surface of which is applied to one of the openings which lead into the labyrinth.

b, *b*, membrane of tympanum; *c*, a long arm of the malleus, attached to this membrane; *d*, the head of the malleus, connected with the incus; *e*, the other long arm of the malleus; *f*, a muscle acting upon it; *g*, the incus, of which one arm is attached to the wall of the tympanum, whilst the other is connected by means of the orbicular bone *h*, to the stapes *i*, and *k* is a muscle attached to it, regulating its movements.

on the other to one of the openings into the labyrinth, and through them vibrations received by the head of the drum are transmitted to the nerve in the labyrinth.

The object of this arrangement is to transmit vibrations originating in air to the fluid in the labyrinth, and thus to the nerve. The membrane and the connected bones perform an office with regard to sounds, analogous to that which the humors of the eye do with regard to light. They bring the vibrations, as it were, to a focus, and make them effective upon the nerve of the ear.

The membrane of the drum answers still a further purpose, analogous to that of the iris in the eye. It is capable of being made tight or lax, according to the intensity of the sound we wish or expect to hear. When we listen very attentively for a minute one, we are sensible of an involuntary change in the condition of the ear, and so too when we anticipate a very loud one; and if a very loud one burst unexpectedly upon us, the ear is often temporarily, and sometimes permanently injured by it, just as happens to the eye from its sudden exposure to a very strong light.

These parts are varied much in different classes of animals; and, although the precise purpose of each variation is not obvious, we cannot doubt that it is intended to adapt the animal to something in its situation and mode of life.

The distinctness of sounds, and the distance at which they are heard, depend partly on their loudness, and partly on their note or tone. Of two equally loud, the sharpest is heard farthest and most distinctly; and of those on the same key, some are heard farther and more distinctly than others, as a fife farther than a guitar or a piano. Some very sharp sounds are inaudible by certain persons, though perfectly heard by others. Dr. Wollaston found, on examining the ears of a number of persons by means of a series of pipes giving the more acute notes, that different individuals ceased to hear at different points of the scale, and were insensible to all sounds above it. Thus some persons can hear certain natural sounds which others cannot, and it is not impossible that there may be a great variety so high in key that they make no impression on the human ear and yet may be perceptible to the animals that produce them. We may thus be surrounded by a world of sound of which we are unconscious, in the same way that we live in the midst of myriads of animals too minute to be seen. Acuteness, as well as feebleness of sound, produces the same effects as to hearing, that minuteness of object does as to sight.

In judging of the direction in which a sound comes, we are aided by a variety of circumstances that experience teaches us to take into consideration. The mere sound alone, does not give us this information. Infants do not seem to possess the power at all. Sounds, as they come to our ears, are modified by reflection, by the interposition of obstructions, and by the position in which the ear is with regard to the body from which they proceed. We generally know from what objects such and such sounds are likely to come, and in what direction these objects are. If we hear these sounds, they appear to come in the direction upon which the attention is fixed.

The power possessed by a ventriloquist of deceiving us with regard to the distance and direction of sounds, illustrates very well the principles which guide us in our judgment. If he turn his face upward and appear to address a person above him, and then imitate a distant sound, the answer will appear to come from above; if he look downward, and yet use precisely the same sound in making the answer, it will appear to come from beneath. He imitates the stifled cry of a dog, and by directing the attention to a closed box it appears to proceed from it. He raises the lid, at the same time changing his voice, and we seem to hear the open cry without obstruction.

Many animals are capable of a much more correct judgment concerning the direction of sounds than man, owing to the size, structure, and movableness of the external ear. This is particularly noticeable in the timid, as the hare, the horse, the deer, &c., and in the nocturnal, as the bat. The external ear in them is long and large, and capable of being moved in different directions. The horse, for example, is, when alarmed, observed to turn his long, conical ear in various directions, and by noting the direction in which a sound is perceived the loudest, he is able instinctively to judge that it comes from that quarter.

In determining distance, we are influenced by the same sort of considerations. When we know the nature of a sound, by what it is produced, and what is its degree of intensity at its origin, we can estimate with some accuracy its probable distance. We can determine when it approaches and when it recedes, by the variation in its loudness. But we are liable to great mistakes in this respect, for there are other circumstances which produce the same effect as distance. Where many obstacles intervene to interfere with and divert the direct passage of vibrations, or where they pass over bad conductors, they are rendered fainter, and appear at a greater distance. Where, on the contrary, there are no such impediments, and sound travels over or through a good conductor, it is louder and appears nearer than it is. The equal density of the air in the unbroken winter of the arctic regions enables it to convey sounds with great facility and distinctness. Generally, over water, they are heard at a vastly greater distance than over land. The firing of the cannon in the memorable engagement between the English and Dutch fleets in the year 1672, is stated to have been heard at a distance of two hundred miles.

The perfection of the judgment with regard to sounds may be much increased, and persons who have been a long time blind learn to elicit from them information for which we ordinarily depend upon sight. "The late blind Justice Fielding," says Dr. Darwin, "walked for the first time into my room, and after speaking a few words, said, 'This room is about twenty-two feet long, eighteen wide, and twelve high,' all which he guessed by the ear with great accuracy."

Instances of this kind show that there are modifications of sound really capable of communicating information concerning surrounding objects to which we do not attend, because we possess by the sense of sight a more certain method of obtaining it. It is quite probable that every object to which the vibrations of sound extend modifies in some measure those which proceed from it afterward by reflection, and thus modifies the whole mass of sound which reaches the ear; for it is to be observed that we rarely hear a sound simply as it proceeds from the body producing it. Even when it first reaches the ear, it is usually combined with some of its own reflections, as will appear from the following statement.

The ear cannot appreciate an interval of sound of less than one twelfth of a second. Sounds, therefore, occurring at a less interval, appear to be one; they are contemporaneous or at least continuous. The consequence is that all reflections or echoes from objects so near that they arrive at the ear in less than one twelfth of a second, are confounded with, or make a part of, the original sound. Now as sound travels through about ninety-four feet in one twelfth of a second, it will be reflected from an object at half that distance at the same interval. Strictly, then, beyond forty-seven feet, the reflection of a sound is distinct from the original; but this is upon the supposition that the sound occupies no time, whilst in fact the shortest does occupy more than one twelfth of a second. A syllable, it is computed, occupies, usually, full one fourth of a second; and an object, therefore, to return the echo of a single syllable, must be at least one hundred and sixty-one feet distant.

Hence it may happen, in some peculiar state of atmosphere, where reflections are returned with great distinctness, that a second sound precisely like the original will be heard at the same time with it, but coming to the ear in a different direction. When this is not the case, the reflected vibrations from all objects within a certain distance will mingle in with the direct ones, and form a part of the original impression upon the organ of hearing. We seldom hear, then, a simple elementary sound, because we are seldom where there are not objects around to modify by reflecting it. A common illustration of this occurs in the difference in the character and volume of the sound of a pistol discharged in a common apartment, or upon an extended plain, or upon a sheet of water.

Probably all objects in reflecting sound produce some change in the quality of the vibrations which is characteristic of their own qualities. A surface of stone, of metal, of wood, of woollen, each modifies it in a way peculiar to itself. It is commonly remarked, for example, how much the sound of music is influenced by the furniture, carpet, and kind of walls, of the room in which it is heard. So that there is probably some quality in every sound, indicative of the nature, form, size, and material of every object which by reflection has contributed to it, as well as of that from which it originally proceeded. A more perfect education of the sense of hearing, therefore, or a more delicate instrument, might enable us to detect by sound many of those qualities of objects which we now know only by touching and seeing. Sight originally informs us of the color and shape only of bodies, but by experience and education we learn to derive from it a knowledge of many of their other qualities. A similar education of the ear in the blind has often given to them a similar power of judging by the sense of hearing. There is an account, in the Transactions of the Manchester Society, of a blind man who spent his youth as a wagoner, and occasionally as a guide through intricate roads in the night and during snow. He was occupied in the latter part of his life as a projector and surveyor of highways in difficult and mountainous regions. In all these occupations he was aided merely by the senses of touch and hearing. It is related also of Dr. Moyes, a blind man, that he could judge by the sounds in a room, of its dimensions, and of the stature of those with whom he conversed. Dr. Saunderson, a distinguished mathematician of the last century, was blind, and we are told authentically of a blind sculptor who produced an accurate likeness of Charles I. by the touch alone. In our own community we are familiar with the almost incredible nicety to which the education, not only of the blind, but also of the blind and deaf, is capable of being carried.

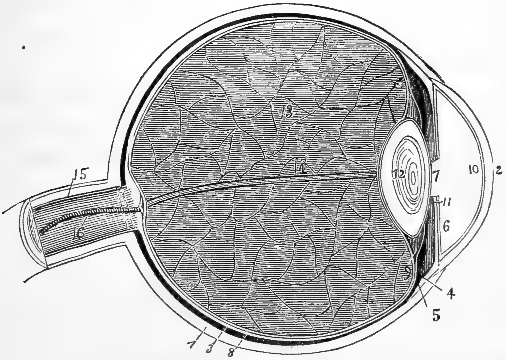
Some interesting inferences may be drawn from these facts, with regard to the construction of rooms for music and public speaking. An apartment in which no part of the surface is more than forty-seven feet from the source of sound is the most perfectly adapted for these purposes. In this case, the reflected sounds will all be practically consonant with the original, and will therefore increase its force on the ear of the hearer. When the apartment is larger, the reflections will interfere more or less with the original sound, and it is necessary for the speaker to articulate more slowly, or rather to leave a longer interval between his words, that the echo of one may subside before another is uttered. The great object is to prevent or neutralize all those reverberations which interfere with the voice, and to take advantage of all those that concur with and support it. A speaker who stands directly under a dome that reflects, and at the same time concentrates, the sound, as a concave mirror does light, may find himself annoyed by a very distinct echo from above, which repeats his words, or, if not more than forty-seven feet distant, utters them apparently at the same moment with himself.

CHAPTER VIII. (W.)

OF SIGHT.—EDUCATION OF THE SENSES AND THEIR COMBINATION AND RECIPROCAL RELATIONS.

In order to understand the structure of the eye, some knowledge is necessary of the general laws of the refraction of light. When its rays pass through a convex lens, they are collected together and form what is denominated a focus. This is an inverted image of the object from which they proceed. If a lens be fitted to a hole in the window-shutter of a darkened room, and

Fig. 47.



In this diagram the eye is supposed to be divided from before backward, so that we look upon the cut edges of the enveloping membranes, and the cut surface of the lens is seen edgeways.

1, Sclerotic or outer coat; 2, the cornea; 3, the choroid or middle coat; 4, 5, 6, the iris and appendages; 7, the pupil; 8, third coat or retina; 9, a canal surrounding the lens; 10, chamber of the eye, anterior to the lens, and filled with the aqueous humor; 11, posterior chamber; 12, lens; 13, vitreous humor filling the posterior chamber; 14, sheath conveying the artery to the lens; 15, optic nerve; 16, artery of the retina.

a white screen placed at its focal distance, a distinct but inverted picture of the objects without is projected upon it. This is a camera-obscura. The globe of the eye is such a darkened chamber, and a similar picture of everything toward which the eye is directed is painted upon a delicate membrane at its back part, called the retina. This impression, conveyed by the optic nerve to the brain, gives to the mind the sensation of seeing.

These are the essential parts of an eye, but in those of different animals a great variety of additions and modifications are observed, rendered necessary by the conditions under which the sense is exercised. We shall understand these modifications best by examining the organ as it exhibits itself in its most perfect state in man.

The eye consists of several external coverings, containing within them certain transparent substances called the humors, which correspond to the lens of the camera-obscura.

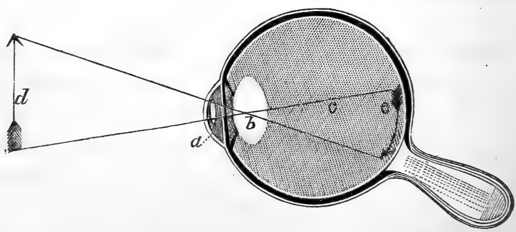
The external covering or coat, called the sclerotic, is a strong, thick membrane, which gives its chief strength to the globe.

The second or middle is thinner and more vascular, called the choroid.

The third or internal is still more delicate and transparent. It is the retina, the screen which receives the inverted images of the objects at which we look.

These coats, as will be observed by referring to the diagram, have an opening at their anterior surface of about half the diameter of the globe. Over this opening is placed, like a watch crystal, the cornea, a transparent covering a little more convex than the rest of the eye, for the admission of light.

Fig. 48.



a, aqueous humor; *b*, crystalline humor or lens; *c*, vitreous humor; *d*, external object; *e*, its inverted image.

Just behind this transparent plate is placed the principal refracting lens, called the crystalline lens or humor. The space in front of this is filled with the aqueous humor, a very thin liquid. The space behind it, constituting the greater part of the cavity, contains the vitreous humor, a jelly-like and more consistent fluid. All these probably contribute more or less to the perfection of the image upon the retina.

Between the cornea and the crystalline lens is placed the iris, the colored circle which surrounds the pupil of the eye. It is as delicate as a cobweb in its texture, and floats in the aqueous humor. It is placed here to regulate the quantity of light which gains admission. This varies to so great a degree that the light of the noonday sun is stated to be 90,000 times that of twilight. By the contraction or relaxation of its fibres, the opening of the iris, or the pupil, contracts with the increase of light, and dilates with its diminution.

The inside of the iris and of the choroid coat of the eye is covered by a black substance like a coat of paint. The transparent retina lies upon this coat. This serves to darken the chamber of the eye, and thus renders the picture on the retina more intense, just as the images on the screen of the camera-obscura are more distinct the darker the walls of the camera itself are.

The globe, thus constructed, is placed in a conoidal, bony cavity, called its orbit. This is considerably larger than the globe, in order to give it great freedom of motion, and furnish room for the muscles by which it is moved. These are six in number, and render it capable of being turned in every possible direction. The rest of the cavity is occupied by a quantity of soft membrane filled with fat, upon which the globe rests.

The eye, being a very delicate organ, is most carefully protected, so that, although placed in what seems a very exposed situation, it yet escapes injury in the most remarkable manner. The edges of the orbit project everywhere to at least a level with, and sometimes beyond, its anterior surface, so that it is secured from the most direct blows, except those inflicted by some small body, as the end of a stick. Even from these it generally escapes by sliding on one side, so that their force expends itself upon the soft parts around. The surface of the eyeball is kept soft and moist by the tears, which are prepared by a small gland situated in the upper part of the orbit. They are diffused by the eyelids in the operation of winking; and in winking not only are the lids brought down over the ball, but the latter is also rolled upward in the socket so as more completely to cleanse its whole surface. All dust or other impurities which are deposited from the air are washed off in this way. When the tears have answered this purpose, they run along the lower eyelid, which has a bevelled edge that forms a little gutter or canal to contain them, toward the nose. There through a small hole they descend into the nostrils. When formed very rapidly, as when the eye is irritated, or in weeping, the canal becomes too full, and they fall over upon the cheek.

The projecting eyebrows shade the eye from the direct rays of the sun, and they also arrest the sweat which might otherwise run down from the forehead, loaded with dust. The eyelashes contribute to the same purpose.

We may, in the next place, attend to some of the phenomena of sensation. When we look directly at an object, we always turn the same point of the surface of the eye toward it, and its image falls always upon the same spot of the retina. A line drawn between these two points is called the axis of vision, or the optic axes. Strictly speaking, we can look distinctly at but a single object at once, and we gain our knowledge of others by directing the optic axes successively to them. But though we can look but at a single object directly, we can perceive the presence of all others which fall upon the retina, and even attend to them, so as to note their color, their shape, their distance, their motions, and also the relation they bear to the object at which we are looking.

The spot of the retina which is the seat of direct vision, though thus used for the most distinct examination of objects, is yet less sensible to impressions of faint light than the portions around it. Thus a faint star in the heavens will sometimes disappear when looked at directly, but reappear as soon as the eye is diverted from it, if the attention continues fixed upon the spot. Late in the afternoon, Venus is occasionally seen in this indirect way, when it is found difficult to see it directly. The same is true of the faint tails of comets, the nebulæ, and the milky-way.

The sensation produced by an object does not cease when its light ceases to fall on the retina. The impression continues for about one seventh of a second, so that we see an object for this length of time after it has vanished. If a body be in rapid motion, we see it not merely where it is, but also in every part of that space through which it has moved in one seventh of a second. If a coal of fire be whirled round in a circle so as to make seven revolutions in a second, it will appear like a circle of fire. When a wheel is in rapid motion, we cease to see the individual spokes. A flash of lightning is actually a luminous spark or ball moving with immense rapidity; but as it passes over many miles in much less than one seventh of a second, it appears to us like a continuous stream of fire. The same circumstance serves also to explain, in some measure, the greater apparent than real number of the fixed stars. It serves also to explain why a body cannot ever be represented in painting as actually in motion. An animal may be depicted with its legs or wings in that position which they take in running or flying, but it always appears at rest, because no art can imitate the appearance produced by the change of place it undergoes in one seventh of a second. Could a photographic image be taken in exactly this period of time, the appearance of motion would probably be exhibited. On the other hand, when a body in motion is seen by a light which does not continue the same period, it does not appear to move. Thus, when a horse and carriage going at a rapid pace is seen by a flash of lightning, it seems to be standing still, and the spokes of the wheel are all distinctly visible, although when seen by ordinary light they are blended into a confused mass.

The point of the retina at which the optic nerve communicates with it, is almost wholly insensible to light, so that an object whose image falls upon it will be invisible. This curious fact is easily illustrated. Let two circles of white paper, four inches in diameter, be affixed to the side of a room at the height of the eye and at eighteen inches from each other. Let the observer then stand directly opposite the left-hand paper and close the right eye. Then let him keep the left eye directed to the right-hand paper, but at the same time continue to take note of the other. Let him next draw slowly backward. At about four times the distance of the papers from each other, that on the left will disappear; but upon retiring still further, it will be again seen. The image at the moment of its disappearance has fallen upon the insensible spot of the retina.

By a little variation in this experiment, the two circles may both be made to disappear at once. Stand directly between them, and with the right eye closed direct the left eye to the right circle, and retire backward till it disappears. Then close the left eye and direct the right eye to the left circle, and this will not be seen. In this position the two objects disappear in succession when looked at with the diagonal eyes. Now place some object at such a distance in front of the nose, the forefinger for instance, that it will hide the left-hand object from the right eye and the right-hand object from the left eye. Look with both eyes at this object, and neither of the circles can be seen.

The iris is closely connected with the condition of the retina, its office being, as already stated, to regulate the quantity of light which falls upon it; so that its opening contracts when the light is strong, and dilates when it is feeble. Other circumstances, however, have also an influence upon it. Other things being equal, it dilates when we look at remote objects, and contracts when we look at those which are near. We see an object in a fuller light with a dilated pupil, but with greater distinctness of outline with a contracted one. The more completely we can exclude all rays except those which come from the object looked at, the better we see it. Thus in a bright day the retina is impressed by all objects whose light falls upon it; the pupil is consequently contracted. But if the eye be shaded, so that all rays are excluded except those which come directly from the object we wish to see, the pupil dilates, and we see it with greater clearness. Hence we shade the eye in a bright light, and we see best from a dark place, or through a long tube, especially if the inside be blackened. From the bottom of a deep well, the stars may be seen by day. In the absence of the sun we see objects which are invisible when it is present, as the moon and the stars, although they give no more light by night than by day.

This, however, does not wholly depend upon the state of the iris. By exposure to strong light the retina becomes insensible to feeble, so that when we go from the full glare of day into a darkened room we are for a time almost blinded from the contrast, and it is only gradually that the retina recovers its sensibility. All our sensations are in some measure comparative, and under different circumstances we are differently affected by the same amount of sound, heat, and light. Even the degree of contraction of the pupil is comparative, since it takes place to as great an extent when we pass from darkness into candlelight, as from the shade into sunshine.

Various other phenomena of vision are connected with the same comparative state of the retina. When the eye has been steadily fixed for some little time upon a bright light or a white object, a black spot of the same size and shape is afterward seen wherever the eye is turned. An analogous effect is produced when the object is of any other color. If a red wafer be stuck upon a sheet of white paper and looked at steadily for a while, and the eyes are then directed to another part of the paper, we see a circle of the same size, but of a light green color, approaching to a blue. The color thus seen after looking at a red object is always the same; and it is called the accidental or complementary color of red. In the same way all the primary colors have their accidental ones, and probably all secondary ones also. The following are the accidental colors of the seven primary, which have been determined partly by observation and partly by calculation.

Primary colors.		*Accidental colors.*
Red,	a combination of	blue and green.
Orange,	" "	blue and indigo.
Yellow,	" "	indigo and violet.
Green,	" "	violet and red.
Blue,	" "	red and orange.
Indigo,	" "	orange and yellow.
Violet,	" "	green and blue.

In order to explain these phenomena, it is necessary to recollect that the combination of the seven primary colors produces a white, and that if any one of them be wanting, the resulting color will vary according to that which is taken away. Thus if red be omitted and the other six mixed, the result is a tint of green; if green be omitted, the result is purple; and so on; and this resulting color is the accidental one of that which was omitted. This fact suggests the following explanation of the phenomena of accidental colors. When a red object is looked at for some time, that part of the retina, which has received its image, becomes less sensible to the red rays of light, according to the common law of all our sensations. If the eye be then directed to a white object, which reflects all the rays, it perceives all except the red, to which it has become insensible. It gets then the impression of an image composed of all the rays except the red; in other words, an image of the accidental color of red. A corresponding effect takes place whatever the original color may have been; and hence has been derived the following definition: "The accidental color of any natural color is that which results from the mixture of all the colors of the spectrum except the natural color itself."

These facts are capable of some practical applications. They indicate a relation of colors to each other something like that of the musical notes, and there is a harmony of colors, analogous to that of musical sounds. An exquisite taste in the combination of colors may be the result of a nice perception of these relations, in the same way that an exquisite taste in music is produced by a nice perception of the relations of musical sounds. It is unquestionable that there are some combinations of color which are universally pleasing and others as universally disagreeable, independently of any associations or acquired habits. This must depend upon some original relation of them to the organs of sense and perception. The arrangement of the colors of dress and their adaptation to the complexion, the principles to be followed in the furnishing of apartments, in ornamental painting, in the manufacture of colored stuffs, all have some connection with these laws. When, for example, as in printing, great distinctness of outline and strong contrast are required, the color of the ground should be the accidental color of the letters. Thus red letters should be printed on a bluish-green ground, and blue upon a mixture of orange and red. When, on the contrary, a gradual blending or gradual intermixture is desirable, so that the eye may rest on a soft and blended mass of light and shade, the juxtaposition of accidental colors should be avoided.

Other interesting phenomena are the result of varieties in the sensibility of the retina as connected with the law of accidental colors. In a room hung with red curtains, their shadows will be observed to have a tinge of green; and when the clouds around the setting sun transmit an orange-colored light, shadows will appear blue. It will also be observed, when a person has been writing early in the morning by candlelight, that toward sunrise, if the rays of light from without become powerful enough to cast a shadow on the paper, it will be tinged with blue.*

In some persons, there is an original incapacity for distinguishing certain colors, although in other respects the sense of vision is perfectly good. There are many who cannot distinguish between red and green, so that the fruit and leaves of the cherry-tree appear of the same hue; whether this be red or green cannot be known, since color is incapable of description. Others can see no difference between green and blue; and very many of the differences of opinion and of taste in relation to colored articles of ornament and dress are probably owing to lesser imperfections of the same nature. These peculiarities, since attention has been called to them, have been found to exist very frequently. The knowledge of their existence in some individuals may be of great importance, as in the case of persons employed to give or to take note of signals by means of colored flags upon railroads, in steamboats, or in vessels at sea, and of those engaged in the sale or purchase of colored goods. Singular mistakes in the selection and matching of dresses have been made from this cause.

There are two questions which have occasioned a good deal of controversy, namely, why from an inverted image upon the

* Under certain conditions of exposure of the eye to the bright light of the sun and the green color of the water in crossing a ferry, the writer has noticed that the black letters of a book have been red. It is difficult, where so many circumstances are combined, to analyze exactly the condition on which this appearance depends, though it is doubtless connected with the same general law, and depends upon some modification of the sensibility of the retina.

retina the mind perceives the object erect, and why from two images, one upon each retina, it perceives a single object.

To the first, various answers have been given, none of them perfectly satisfactory. Probably none can be given. When we can explain how from any image at all the mind perceives the object from which it proceeds, we may be able to attain to a sufficient solution, and not till then.

In regard to the second there is less obscurity, and yet the solution is somewhat complicated as well as difficult; to some it may appear unsatisfactory. The range of absolute single vision may have been overrated. It seems probable that only one object, or very strictly speaking only one point of an object, is seen singly at once. This point will be that to which the optic axes are both directed; and of course they will there cross each other. The object placed at this point, where the axes meet, will appear single; all other objects, so situated that they can be observed by the mind without turning the eye toward them, will appear double.

They appear single, simply because their two images are in the same place *as respects the eye.* But they are in the same place *only* as respects the eye. For if, when looking at any object, we shut first one eye and then the other, the object appears to move, because then we notice its place *as respects other objects.* Place is merely relative, and, so far as single vision is concerned, it is determined by the relation which the object bears to the eyes and to the optic axes.

In this view, the place of bodies is constantly changing. When a finger is held up between the eyes and a candle, if we look at the finger, we see two candles, one upon each side of it; if we look at the candle, we see two fingers, one upon each side of the candle. But the single candle is not in the same place where either of the two appeared to be. When the eye is shifted from the finger to the candle, the two candles move together and form a single object, midway between the double ones. The candle then is, during the experiment, seen in three *apparent* places.

When the eyes, then, are both directed, and the attention fixed, upon the same object, its minute relations to surrounding ones are disregarded, place is considered only in respect to the eye, the images both occupy the same apparent place, and they consequently seem to be one. But it becomes double as soon as the attention is diverted to other bodies.

These remarks suggest the most probable explanation of the beautiful phenomena of the stereoscope. In nature, we see all objects in two places as it regards other objects except that at which we are directly looking at the moment. In an ordinary painting, we can only see them in precisely the same place with both eyes. Hence, however perfect may be the drawing, the coloring, and the perspective, that relation is wanting with which we have learned to associate the actual external appearance of the objects represented. But when two pictures are looked at, one of which represents things in the relation in which they appear to each other with one eye, and the other in the relation in which they appear with the other eye, in other words, when they are represented in different places as respects each other, then they appear as in nature, not only with the light, shade, perspective, and perhaps color, but also with that duality of place which gives the impression of distance, depth, and relief. With regard to near objects and single ones, their difference, as seen with the two eyes, is small; but where many are present, and at different distances, it is very considerable. Any one can satisfy himself of this, by looking at any deep landscape, with the eyes alternately. As the eye first used is closed and the second opened, a relative motion immediately takes place in the different objects seen. If the two pictures employed in the stereoscope be compared, we find in their minute details a great many small differences of relative place in objects, like those we perceive in nature, when looking successively at objects with the two eyes alternately. The more numerous are these objects, and the greater their intricacy and varieties of distance, the more perfect will be the appearance of reality.

By education and experience we learn to derive a great deal of information from the sense of sight, which it does not originally afford us. At birth the eyes are perfect in structure, but are moved in their sockets almost at random, and not fixed steadily upon objects; and it is doubtful if the mind takes cognizance of anything but the simple sensation of light. Gradually, particular things are looked at. The information derived from the eye is instinctively compared with that from the other senses, and, after a while, we come to depend upon it for the greater part of our knowledge of the external world.

In judging of the position of other bodies, we are guided by a reference to that of our own, especially its relation to the plane of the horizon. The natural posture of man being erect, he can only maintain his perpendicularity by the harmonious action of a great number of muscles. We are constantly operated on by causes which tend to throw us from our equilibrium, and we are as immediately sensible to any deviation from it, as the balance-master to the most trifling inclination of the object he is balancing. We restore it by an effort, the result of a habit which has been instinctively acquired by a slow process when we were young. It is mainly by the sense of seeing that we do this. The rope-dancer would fall to the ground immediately, if suddenly deprived of the use of his eyes.

We judge then much of the position of other bodies by an insensible comparison of them with ourselves, — with our own feeling of our own position. In this way, for example, most persons can form an estimate of any considerable deviation from perpendicularity in the walls of a house, the columns of a building, the trunk of a tree. Independently of visible objects, however, we are much aided in maintaining our own perpendicular position by a perception of our own gravitation, and in blind persons it is preserved by this alone.

In a ship at sea both of these aids are disturbed, and consequently, till new habits are formed, it is difficult to stand or walk, whilst at the same time various other related phenomena are observed. When standing in the cabin, a lamp hung from the ceiling *appears* to oscillate slightly around a perpendicular line, while every surrounding object seems to depart from it; and this it really *does*, and as we are making strong efforts to stand erect, we do not lose our reference to the perpendicular, but by the feeling of gravitation perceive any considerable deviation from it. But when we lie down in a berth we are relieved from the effort to stand erect, and consequently lose the perception which guides our judgment of perpendicular position. At once the lines which formerly seemed perpendicular, and which really were so, apparently become oblique, and swing in various directions, while the parts of the vessel itself appear more nearly stationary. Articles of clothing, for example, appear to swing out from the side of the state-room, at variance with the direction of gravitation, whereas they in fact are retaining this direction while the surface against which they hang has departed from it. The deception is not in this case entirely complete, since we are never entirely insensible to the direction in which the force of gravity acts.

With regard to the real and relative places of objects, their distance, magnitude, and motions, we are liable to constant errors; yet we are still able to form judgments sufficiently accurate for the common purposes of life. In our estimate of distance, we insensibly take into consideration a variety of circumstances. Within short distances we are guided partly by the effort required to adjust the eye to them, but principally by an instinctive perception of the effort made to bring the optic axes together upon the object looked at. With one eye shut, a person finds it difficult to perform many simple and common operations, as snuffing a candle, pouring out a glass of wine, putting a hook through a ring; he finds that he either comes short of, or goes beyond the object.

When the distance is such that the optic axes are nearly parallel, our judgment is more imperfect. Where the object is a known one, we take into view our knowledge of its size. The *apparent* size of an object depends upon the size of its image upon the retina. As it is removed further off, this image becomes smaller, and of course the object appears smaller. But if the object be a familiar one we are not deceived. We make allowance for distance in judging of size, and for size in judging of distance. When the *real* size of an object then is known, we judge of its distance by its *apparent* size. When its distance is known, we judge of the real size by our knowledge of its distance. But it is obvious that in such cases we only approximate to a correct estimate.

When there are no other circumstances to guide us, things which are seen the most vividly and distinctly appear the nearest. In twilight, when we are deprived of many of the usual means of judgment, we are liable to great errors of vision. Those things which are of a light color or are placed in a strong light appear nearest. A fire in the night seems always much nearer than it really is. Of a number of lamps in the streets of a city, the brightest will appear the nearest, unless their position be otherwise known. Of the heavenly bodies our first impression is that the most brilliant are nearest to the earth. Hence some of the fixed stars appear nearer than the fainter planets, though they are actually many million times farther off.

The objects which intervene between us and a distant one aid us in forming our judgment of distance and size. In looking at a distant mountain we glance over the intermediate space. If it present to us a landscape composed of smaller hills, valleys, farms, villages, rivers, and lakes, we conclude that the distance is great and the mountain large. If, on the contrary, we look only over a bleak and uninhabited plain, we underrate the distance, and the mountain appears small. Hence partly the disappointment often experienced upon first beholding very large objects, the pyramids for example, under such circumstances. For the same reason, large objects seen over the water appear comparatively small, and their distance also much less than it really is, except to those whose habits enable them to make allowance for sources of error.

Objects seen on the same level with ourselves appear more nearly of their real size and distance than those either above or below us. From the steeple of a church, a man looks very much smaller than when seen at the same distance on level ground. A weathercock, which is so small an object when seen at a height of an hundred and fifty feet, seems very large when seen at the same distance on the earth. In both cases the picture on the retina is of the same size, but in the latter our daily experience has taught us to take into consideration the effects of distance on the apparent size, in the former it has not. The same is true of the apparent size of the sun and moon, as seen near the horizon, and when at a high altitude.

Our judgments concerning the various motions of bodies are more complicated. The most simple idea of the motion of an external body is derived from the movement of its image over the retina. When the eye is at rest and an object moves, its image traverses the retina, and we are informed of this motion. But if the eye moves in its socket, or we change the position of our bodies, the image also traverses the retina, but we do not get the idea of motion. This is because we know that the eye, or the body, moves. All motions of images on the retina, therefore, do not give the impression of motion, but only those which are produced by the actual change of place in external things, or else by such motions of the eyes or the body as we do not take cognizance of.

We learn instinctively to take this into consideration in forming our estimate of motion; still we cannot always do it with equal accuracy. We are usually aided by a reference to objects around us that we know to be stationary. But where there are no such objects, we are liable to deception in our sensations, and to mistake in our judgments. When two railroad carriages stand side by side and one of them is put in motion, a person sitting in one and looking at the other cannot tell which it is, unless he compare it with some body which he knows to be stationary. When we are moving in a vessel on the water, in the midst of many others, it is almost impossible to tell which are also moving, and which are at rest. In riding through a grove of trees, not only do they seem to move past us in consequence of our own progress, but they appear to move in regard to each other, crossing and passing away in opposite directions, with various degrees of rapidity, and with motions so complicated that, did we not *know* they were stationary, we could not determine from the information of sense alone that they were so. The heavenly bodies appear to us to move from east to west, although we are ourselves moving in the opposite direction, because everything immediately around us is at rest with regard to ourselves.

There are many circumstances under which apparent motions of external objects take place, that require to be explained. When one of the eyes is pressed a little out of its direction by the finger, the object at which we are looking appears to move. The drunkard fancies that the earth is rising up under his feet, or that the walls of his room are falling over upon him. The sick man sees objects whirling around him or dancing strangely about. When the mind is disturbed by delirium, these are judged to be real phenomena; in health, we know them to be deceptive, but the impression on the sense is not the less vivid. The following is the explanation.

In the natural condition of the organs of this sense, they are kept under the control of the will by means of the muscles which move them. The mind takes note of all their motions, and when images pass over the retina in consequence of these motions, it judges that the apparent change of place in external objects is due to them. But when this control over the organs is lost, when they are moved independently of the will, or when the mind ceases to be capable of taking note of and allowing for their motions, then the passage of images over the retina produces the impression of actual motion in external bodies. If the eyes be examined when these phenomena are present, they will appear unsteady in their sockets, and affected with a capricious and tremulous motion. In the dizziness produced by turning rapidly around, the eyes will be found to have a quick, alternate, horizontal movement from right to left, and from left to right; of this the person takes no cognizance. Consequently, as he is not conscious that the eyes move, the impression produced is that the objects around him move rapidly in a horizontal direction; but if this motion be very carefully analyzed, it will be found that it is, like that of the eyes, to and fro, and not continuously in the same direction.

These irregular phenomena are frequently the consequence of a disturbance or disease in the brain and nervous system. On the other hand, actual irregularities in the motions of external bodies will in some persons produce a disturbance in the brain and nerves. This happens when the motions are such that the eyes cannot be steadily fixed upon and follow them. This is one of the causes of sea-sickness, which is much relieved, and sometimes prevented, by lying down and closing the eyes. Many persons cannot look at a body moving rapidly in a circle without becoming dizzy and sick. The motions of dancers in a ballroom, the tossing of waves, the swinging of a looking-glass in the air, have all been known to have the same effect, and from the same cause.

We proceed next to an account of some of the circumstances in which the eyes of animals vary from those of man, in correspondence with differences in their necessities, habits, and modes of life.

The head and face are the residence of all the senses except feeling and touch, and in very many animals the true touch is actually exercised by some part of the face, mouth, tongue, nose, and lips, as in the ruminating and pachydermatous animals, especially the elephant and tapir. It is worthy of remark, that even in our own species the first impulse of the infant is to carry every object which it handles directly to the mouth, as if it could thus best judge of its sensible qualities.

Much of the expression of the countenance in man and animals depends upon the relative proportions of the head and face. A large head and small face give an intellectual and agreeable expression; a large face with a small head, an animal and sensual expression. Connected with this difference is a difference in the development of the senses of seeing and hearing as compared with those of smelling and tasting. As we depart from our own species and examine the lower animals, we find the face increasing in length and size, whilst the head diminishes. The organs of smell and taste increase, whilst those of seeing and hearing not only do not increase, but, in many cases at least, actually diminish in proportion to the size of the whole head and the whole animal.

This difference indicates the relative importance which these senses maintain in the constitution and character of the animal. When we find that, as the size and capacity of the organs of smell and taste increase, those of sight and hearing and touch remain stationary or diminish and become less perfect, we infer that, though distinct perceptions may be still derived from these last senses, yet that the former, physically considered, predominate in the character. No doubt the mere perception from sight is as perfect in the quadruped as in man, but the range of information he derives from the sense is very small, whilst that which he derives from smell and taste is very great. The increasing predominance of these lower senses indicates the decreasing empire of intellect and feeling, and the increase of that of simple physical propensity.

Vertebral animals have two eyes, and their structure is mainly like that in man. The orbits are also, like those of man, of a conoidal shape, the apex within; but their direction, as respects the rest of the head, varies a good deal. In man, the axis of the orbit is directed forward and a little outward; in the monkey tribe, slightly inward, whilst the distance between them is smaller. This gives them a peculiar expression. A greater or less approach to the same is often seen in some individuals, and some of the races of mankind. It is often taken to indicate a species of cunning like that of apes.

In other animals the direction of the eyes varies very much. Their axes separate from each other more and more in the carnivora, the rodentia, and the ruminant tribes. In some of them it is impossible for both of them to be fixed at once on the same object, and of course the harmonious action of the two eyes which exists in man is destroyed. Such also is the arrangement in some birds, reptiles, and fishes. In one species of fish, one eye looks downward, the other upward. In the flat fish, as the flounder, halibut, sole, &c., they are both upon the same side of the head. In whales, which live upon the surface of the water, both are upon the top of the head. In some lizards there is a voluntary power of controlling the motions of the eyes separately, and of directing each eye to a distinct object.

When the eyes are situated so far upon the sides of the head that they cannot be both directed to the same object, a single eye only is employed, and the attention is fixed only upon the image conveyed by this. This arrangement has an intimate connection with the character and habits of the animals in which it exists. It is found in the most marked manner in those which are timid, and liable to become the prey of others. The strongly-marked carnivorous species, the cat, lion, leopard, wolf, the eagle, the vulture, the owl, have the eyes directed forward, whilst in the hare, the deer, the squirrel, and a variety of others, both among Mammalia and Birds, they are placed upon the side. Such animals, doomed to be pursued and devoured by others, are thus, with a very slight motion of the head, enabled to look behind and before. One eye is turned in front and the other in the rear. By habit, they learn to transfer the attention rapidly from one to the other, so that their field of view practically embraces both directions, and whilst they keep watch upon the enemy who is in pursuit, they can at the same time look forward to select the path which will most effectually lead them to a place of safety.

The size of the eyes bears no exact proportion to that of the animal. In some of the larger animals, as the elephant, whale, and rhinoceros, they are relatively very small, whilst in some of the smaller, on the contrary, as the hare and the squirrel, they are very large. In the subterraneous they are again very small, as in the mole and the meadow rat. Birds and fishes have large eyes in proportion to the size of the head. So far as we can judge, the size of the eye bears rather a relation to the kind and quantity of light to which the individual is exposed, than to the size of its body; and a very large eye is often, though not uniformly, to be taken as an indication that the animal is capable of seeing very well in the dark. The bat, it is true, has a small eye, but then it is capable of directing its flight by other means than sight, whilst moles and other subterraneous animals derive material aid from the sense of hearing.

The power of adapting the eye so as to see objects distinctly at different distances varies much in different animals. Were its optical powers always the same, there would be only one distance at which the image could be accurately formed on the retina. The rays from all nearer objects would come to a focus behind the retina, those of more remote before it, and the sight would be consequently confused. In man, the range of the distinct vision of minute objects is quite limited. It extends only a few feet. The same is probably true of a large proportion of quadrupeds, though they are capable of seeing things much nearer to the eye than man, a provision rendered necessary by their use of the mouth as the organ for seizing their food. Man has accordingly a less convexity and a less density of the crystalline lens, and he sees distant objects more distinctly.

But Birds require a much greater range of vision in order to adapt them to their mode of life. The common species, which do not often rise above the height of an ordinary tree, are more highly endowed in this particular than any quadruped. The domestic fowl, while it is supplying its young with food only an inch from its eye, will the next moment perceive a bird of prey at a great height in the air. Birds that feed on worms and insects can see them on the ground from the top of a tree, and on alighting, can then perceive them with equal distinctness when almost in contact.

By birds of prey this power is possessed in a still more remarkable degree. Those which prey upon fish plunge from a great height directly into the water, and must not only have perceived their object at first, but have kept the eye fixed upon it during their whole descent. This implies a constant and rapid change in its optical condition. It is related of the kite that it has been known to discern and direct its course toward a lizard in the grass from so great a height that it had been itself invisible. The power of remote vision is even more remarkable in the vulture. A traveller of good credit relates that, having once killed an animal and left it on the ground before his tent, he perceived, after a while, a small speck in the remote heaven, which, as it gradually approached, proved to be one of these birds directing its course to the carcass. In less than an hour he was joined by seventy others, flocking from various quarters. These must have been all guided by sight, and the eye in such cases actually combines the powers of the telescope and microscope; on the one hand seeing objects very minute and near, and on the other, those very remote, with equal accuracy.

There can be no doubt that this result is brought about by a nice adjustment of the parts of the eye. The exact mode is, however, too imperfectly understood to admit of a satisfactory explanation.

The eyes of Fishes require a modification, growing out of the great density of the medium through which light comes to them. The refracting power of the humors needs to be very much increased. In man, a considerable part of the refraction takes place upon the convex surface of the aqueous humor, which is much denser than air. But he cannot see under water, when the eye is in contact with it, however transparent, because the rays come from so dense a medium that they do not undergo such a refraction as will produce a distinct image. So too in Fishes, very little if any refraction is produced by the aqueous humor, but we find, instead of the soft and slightly convex lens of Mammalia and Birds, one which is nearly spherical and much more dense; at its centre, of almost a stony hardness. It is obvious in what way this structure adapts them to the dense medium in which they live.

There are some common facts connected with this statement which require explanation, as they seem at first contradictory to it,—such as the exercise of sight by persons with regard to objects at the bottom of the water, as by divers and those in a diving-bell, and by fishes, who see objects perfectly well in the air above them and on the banks of rivers and lakes, when they are themselves in the water.

It is only necessary to state that a medium does not affect the formation of an image in the eye, unless it be directly in contact with it, or unless it have, from its shape, produced a refraction in the rays which pass from it to the eye. Hence the difference between looking through a plate of plain glass and a lens. Now if the eye be out of the water and the surface be perfectly smooth, we can see through it as well as through glass. But not so if we dip the head beneath it, so that it comes in contact with the eye. Then vision becomes very indistinct. Pearl-fishers can see only a short distance, and that very imperfectly; whilst with those who descend in diving-bells the air continues to be the medium of vision, and they are hence able to see very well where there is sufficient light.

In the same way the vision of Fishes is explained. The fish while it remains in the water, if its surface be smooth, sees objects in air as plainly as we do in water. He sees insects on the surface, birds in the air, the fishermen on the shore. But when drawn upon land, objects become as indistinct as they are to us when we are under water.

The only condition necessary to enable an animal to see from its natural medium into another, both being sufficiently transparent, is that the surface of that into which he looks should be perfectly plain and even. Grinding a plate of glass does not render it less transparent. It destroys the evenness of its surface by breaking it up into an infinity of small irregular surfaces, each of which refracts differently, and thus disperses the rays of light passing through it. So, too, the agitation of the most transparent water produces an irregularity of refraction at the surface which prevents our seeing to any depth. For the same reason, under these circumstances, fishes cannot see out of it, and hence the well-known advantage to the fisherman of such a disturbance.

Mere motion in a transparent medium does not interfere with the direct passage of rays and with distinct vision, unless it be accompanied by such an inequality of its surface. We see through the air as well in the highest wind as in a calm; and to the bottom of a rapid stream, if it flow on with an unruffled surface, as well as of a quiet lake. But if motion be accompanied by an inequality in the density of different parts of the medium, or an irregularity of its surface, vision is more or less imperfect. We have examples of this during the solution of transparent salts in water, and in the columns of heated air which are seen arising from a heated body. Upon the same cause depends the greater indistinctness of objects when seen through the unequally heated air of summer, as compared with the cold and equal atmosphere of winter. The ground-glass shade of our lamps diminishes but little the amount of light diffused through an apartment, but it prevents entirely our discerning the form and outline of the flame.

The habits of some animals require that they should see both in air and water. Such are the whales and other cetaceous animals, the frog, tortoise, alligator, crocodile, &c. In animals of this description, the structure is somewhere between those of Mammalia and Fishes. The crystalline lens is more convex and more dense than in quadrupeds and birds, but less so than in fishes. It is probable that their vision, both in air and water, is somewhat imperfect; that they cannot see so well in air as quadrupeds and birds, nor in water as fishes. There is something in their history which confirms this. Are there any facts which show that reptiles are possessed of a keen sense of sight? May not the alleged ease with which the attacks of crocodiles and alligators are foiled be partly owing to their imperfect vision? May not the ease with which the whale is subdued by means so insignificant, and the apparent stupidity shown in his attempts to escape, depend rather on a defect of accurate vision than on any real want of sagacity?

There are many varieties in the form and structure of the eyebrows and eyelids, which serve to illustrate the circumstances under which vision is exercised by different animals. We have room, however, to notice only a single provision, — the third eyelid or nictitating membrane in birds. Birds, like the Mammalia, have two principal eyelids, an upper and an under; but, beside this, they have another, whose uses and motion are peculiar. It is a loose membrane lying folded up at the inner corner of the eye, but capable of being drawn across it in a horizontal or rather an oblique direction from within outward. It assists in the operation of winking. It does not move with the rapidity of the other lids, but more gradually. It is best seen in those which have a large cornea, as the owl; and its slow and very distinct movements in this bird give to it an expression of almost ludicrous solemnity. It is brought out more rapidly when the animal apprehends that some foreign body is about to touch the ball. This is not its only use. As it is not entirely opaque, it still permits an imperfect view of external objects, and defends the eye not only against very strong light, but against injury from leaves, grass, bushes, and branches of trees, among which the food is often sought.

Fishes have no movable eyelids. In fact, the skin is continued over the orbit, becoming transparent where it corresponds to the globe of the eye, and inclosing it in a cavity, the anterior part of which is thus secured as it were by a plate of glass. The operation of winking is rendered unnecessary by this arrangement, and the tender organ is also protected by it from the rough contact of the various bodies which are constantly floating in water.

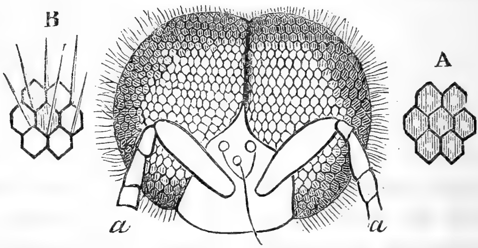
Among all the vertebral animals the eyes are modelled upon the same general plan as those of man; but in the other branches we find organs clearly intended for the same function, where the object seems to be brought about in a somewhat different way.

The minute structure of the organ in these animals, by which the rays of light are prepared for the retina, is not entirely understood. It is pretty certain there is no complicated refracting apparatus like that already described. We are forced to the conclusion that in these cases light operates in a manner somewhat different from that in which it does in Man and the other Vertebrata, and that it may produce vision by its simple conveyance to the nervous surface without refraction; the transparent medium merely serving to transmit it, and to protect from injury the delicate structure necessary to receive the impression.

Of this description are the eyes of Insects. They are either simple or compound. The simple consist of a single lens of which there may be a variable number. They are not uniformly situated, but in different species occupy different parts of the head, and are sometimes, as in the case of some of the crustacea, elevated upon a footstalk.

A compound eye is composed of a number of six-sided lenses or transparent plates. Their number varies from one to four, and the number of lenses from fifty to near 25,000. Under a microscope of moderate magnifying power, they are easily seen in the common house-fly, where they form the two brown, projecting, hemispheroidal protuberances upon the sides of the head.

Fig. 49.



Compound eyes of the bee magnified *a*, *a*, antennæ; A. hexagonal lenses still more magnified; B. same with hairs growing between them.

One reason for endowing insects with such a number of eyes is to compensate them for their want of power to turn them in various directions. Instead of turning the eye from one object to another, they simply turn the attention from the image produced through one lens to that through another, and in this way are probably able to estimate the direction, distance, and relation of objects. Of the sense of sight in those animals still lower in the scale, our knowledge is too imperfect to render it expedient to enter into its consideration. It is only to be remarked that the more minutely their structure is investigated, the more there appears reason to believe that it is possessed by those formerly supposed to be destitute of it, and that it is also exercised in them by distinct organs of vision.

In the full possession of our faculties in adult life, the control of the senses and the power of deriving knowledge from them seem to be an original possession. This, however, is not so. The infant comes into the world in entire ignorance, not only of the qualities, but of the very existence, of anything beside himself. A dim consciousness of his own being and of his own sensations is all that belongs to him. By means of his senses, his perceptive and reflective powers, he slowly acquires a knowledge of the world without himself, and the relation he bears to it.

The senses require to be educated. But there is in fact no improvement in the senses themselves. Actual sensation, for aught we know, is as perfect in the infant as in the adult. The impressions received are probably the same at all ages, while the organ remains healthy. The education is wholly within the mind, and depends upon an instinctive observation, comparison, and judgment of the various impressions that are received.

At first each sensation is referred to a distinct origin. The infant has no idea that the object whose taste was grateful to him is the same he had just smelt, or that the one he had smelt was the same he had just touched. So of sight. He cannot know that the object he sees is that which he has just felt. He learns this association only by experience, and learns it slowly. Light affects him pleasantly very soon. Bright objects attract his attention, and the sensations they produce are agreeable, but nothing further. His earliest moments are spent in training the sense of touch, and, in connection with it, the organs of motion. His time is occupied when awake in a variety of vague and irregular motions, which seem for a long time to have no purpose. By them he gradually learns the use of his arms and hands, and associates the perception of their motions with the appearances they exhibit to the sight.

It is principally touch and sight which are educated together, and have the most important influence upon each other. The sense of taste perhaps gives an original impulse to that of touch; but it is by the aid of the latter combined with sight, that we lay the foundation upon which is built up our knowledge of the external world. The first step is to learn when these two senses are operated upon by the same object, and there is little progress made till this has been taken.

It is by the touch that the child first learns the existence of anything beside itself. An odor, a taste, a sound, do not necessarily imply it. They may be merely the affections of the percipient principle itself. It is different with the touch and feeling. When the infant touches his own body he has a double sensation,—in the part which touches, and the part which is touched. When he touches another body it is not so; the sensation is single. When he thrusts his hand into his mouth, he feels his mouth with his hand, and his hand with his mouth. When he puts his rattle there, he perceives that it is an object which bears a different relation to him, and thus he gets the primary distinction of a foreign body.

This distinction is gradually taught to the sense of sight, and by repeated observations and comparisons he learns to associate together the impressions derived from the two, to correct the information derived from one by the other, and by degrees acquires all that minuteness and accuracy in the knowledge of the things about him which he at last possesses. The first steps in this process are made slowly and with great difficulty; but when they are once taken, the subsequent progress becomes easy and rapid.

The sense of touch then is the chief educator of that of sight; and it is partly owing to the absence of any such educator of hearing, that the infant is so much later in deriving knowledge through this inlet. It is partly, also, owing to the fact that the sense of sight may be at all times exercised upon all bodies, whilst sounds are only occasional; they are not given out by all bodies, nor by any bodies at all times.

The first sounds distinctly appreciated by the infant are probably those made by himself; though loud and sudden ones produce a shock that is noticed. He exerts the organs of voice at first as he does his limbs, instinctively, but without distinct purpose. By and by he discovers that certain efforts are accompanied by certain sounds, and this association is gradually followed by a succession of others; but his advance in the knowledge of sounds is far more slow than in that of colors, and principally for the reason just named, that color is a constant, whilst sound is only an occasional, attribute of bodies. It is also difficult to refer sounds to their origin, and the touch does not in this case aid us as it does in that of the eye. We cannot be sure that the body we touch is that which has emitted a sound. It is only after a considerable advance has been made in the education of the sense of sight, that that of hearing arrives at a tolerable degree of accuracy.

But though thus so late in its development, hearing ultimately becomes as important as seeing. Merely as animals, having certain wants to satisfy and desires to gratify, there is no doubt of the greater value to us of the sense of sight. But when man is regarded as an intellectual, moral, and social being, the sense of hearing assumes an increased relative importance. Upon this depends voice and language, the medium by which we communicate with the rest of our species. By it we receive much of our knowledge; by it the intellect is cultivated; by it the emotions, affections, and passions are excited, and by the voice, which is trained only by its aid, they are expressed. It is the great agent of human intercourse; and, although human ingenuity has devised means of obtaining the entrance of language to the mind through the senses of sight and touch, yet this is but a secondary use. The origin of language depends upon the sense of hearing.

It is worthy of remark, that after the senses are completely educated we mainly depend, in our intercourse with the external world, upon those from which we originally get the most imperfect information,—sight and hearing. It is difficult to imagine, were we confined to these two from the first, how we could make any progress in our knowledge of other things than ourselves. So far as we can judge, the scene about us must appear like a dream, a vain and unsubstantial vision.

There are various other relations of the senses in man that it would be interesting to point out, but this would lead to too wide a discussion. It is only necessary to remark further, that, although in this analysis of their office and education they have been spoken of as developed and educated in succession, this is not strictly true. The sight does not wait till the touch is perfected, nor the hearing till both have been fully instructed. There is the order of precedence which has been pointed out in the degree of progress, but the education of all begins as soon as they begin to receive impressions, and advances with a rapidity proportioned to the necessities of existence, and to the development of the internal powers to which they are subservient.

Among the lower animals, there is a great difference in the capacity for the exercise of the senses which they manifest at birth, and the amount of education necessary in order to their perfection. Generally, however, they come speedily to their perfect use; and that capacity for employing them, which in man is the result of a course of training, is in them instinctively possessed. The chicken, as soon as it has left the egg, can not only see and hear, but can judge at once of the distance, position, and magnitude of bodies, of the direction and import of sounds, and can direct its voluntary movements in conformity with this knowledge. This difference depends not upon the organs of sense and the organs of motion, but upon the internal principle with which these are associated and by which they are directed. The chick comes into existence possessed of an instinct already instructed and informed. Little is left to intelligence or education. The infant, on the contrary, has few informed instincts, but it has instead an intelligent principle existing in embryo, destitute of knowledge, and capable of arriving only by a slow and laborious, though still an instinctive, process at the same capacity for receiving and judging of the impressions on the senses.

The senses, taken all together, in man are superior to those of other animals, simply because he possesses the best means of educating them; and this is done chiefly by the perfection of his touch, in which he excels all, whilst in particular senses he is excelled by many. Quadrupeds derive impressions through the organ of smell, of which we have no adequate conception. In the dog, for example, it is the test to which he brings every new object. He does not trust to sight or hearing alone. He judges by his smell, as man does by sight. The fondness which he at once shows for some individuals seems to be of the same nature as the agreeable impression often made upon us at the first sight of a stranger. The dog who has been long absent from his master is never satisfied of his identity till he has subjected him to this ordeal. In Birds probably the sight is predominant, and in Fishes hearing. Still there is much that is difficult to account for, in regard to the information derived by animals — so far as we know — from the senses they have in common with us. How do birds direct their course in their long migrations, and arrive always safely at their destined end? How do fishes pass from sea to sea and up the course of rivers with such unerring certainty, through a waste of waters which can bear no marks for their guidance? Man does similar things only as the result of long experience, careful observation, and by bringing to his aid the discoveries which science has slowly accumulated. The history of the whole animal creation is full of phenomena really as wonderful as these.

So remarkable are some of those exhibited by insects, that it has been even supposed that they may possess senses which we do not; at any rate, it is certain that they derive information from external objects, to which we are always strangers. Still the organs by which this is done have not been detected, and it is not even certain, with the exception of the eye, what is the distinctive function of the several parts which are obviously concerned in conveying to them information about sensible objects. Facts have been stated which render it probable that the antennæ are the seat of hearing; but beyond this there are also circumstances which appear to imply that they are not only the seat of combined powers of sensation, of which we have no clear conception, but also of reciprocal powers of communication. Some examples of this sort will be found in other parts of this work in relation to ants. Huber records a very remarkable one of bees. When the queen is taken from a hive, great consternation is manifested as soon as the loss becomes known through the community, and every absent individual, as he returns, is at once informed, and takes part in the alarm. In order to determine how the fact was communicated from one to another, a hive was divided into two parts, by a grating which prevented the contact of the antennæ of the animals on its two sides. Those remaining with the queen continued perfectly tranquil. Those upon the other side of the grating were thrown into a state of great agitation, and after a while, not discovering their ruler, proceeded as usual to take means for the preparation of a successor. The division was then so arranged that the antennæ could be brought in contact, but no other part. No consternation ensued, but a constant communication was maintained across the grating, by touching the antennæ, and the queen was stationed at the dividing line, constantly occupied in answering the inquiries and quieting the apprehensions of her faithful subjects.

Bees, like dogs, distinguish persons, remember them, and exhibit a singular preference for some and antipathy to others. Some persons, taking advantage of this peculiarity, have been able to handle them with impunity, and by making captive the queen and removing her from place to place, have caused the whole swarm to settle upon and to move over different parts of their bodies.

Many insects are extremely susceptible to the influences of weather, and this may probably be due to that peculiar compound sensibility of the antennæ just referred to. Ants are highly endowed in this particular. Although they daily bring out their larvæ to warm them in the sun, they never suffer themselves to be overtaken by rain. Many other insects are aware of the approach of foul weather, before any signs of it are obvious to us. Bees foresee a shower long before its approach, and return suddenly to their hives. When they wander far from home and remain abroad late in the evening, it is an indication that the ensuing day will be fine. When, on the contrary, they remain near at hand, and are seen frequently going and returning, rain is pretty sure to follow, though we can discern no sign of its approach. Perhaps this extreme sensibility may be connected with a hygrometric property of the antennæ, or a power of appreciating electrical changes in the atmosphere.

CHAPTER IX. (W.)

REPRODUCTION AND TRANSFORMATION.

The production of one living thing from another, and its first coming into existence, is a mystery into the intimate nature of which we cannot hope to penetrate. We are well acquainted with some of the details of the process, but the mode in which the principle of life is transmitted from one being to another, and by which it is able to convert common matter into a living tissue, eludes our observation. The medium of this transmission in the case of the plant is a seed, and in the animal an egg. The nature and purpose of these two bodies is essentially similar. Each is the germ of the new creation. The circumstances in which they differ have been before pointed out, but those in which they resemble each other are quite as striking.

The egg may be developed and nourished within the body of the mother, in which case the young are born alive; but in by far the larger part of the animal kingdom it is thrown out by the parent, and goes through a subsequent process, called incubation. A certain degree of heat is necessary to this, as is shown by the fact that some degree of cold will arrest it.* The eggs of many insects are laid in the fall, but remain dormant through the winter, the heat of spring or summer being necessary to their development. Among birds, a more equal and constant as well as a higher degree of warmth is necessary, and this is usually supplied by the body of the mother. In hot climates the external

* In birds, a heat nearly approaching that of the parent animal is required. In reptiles, fishes, insects, &c., the temperature of the medium in which they live at the breeding season is sufficient. How low the temperature may fall without arresting the process in the lower classes is not certain. In the arctic regions, during the summer, insects appear in great numbers when the thermometer rises to 45° in the daytime, although during some part of every day it falls many degrees below the freezing point. Probably, therefore, the embryo is frozen during some part of every day during the whole process of incubation; but it is not likely that any active progress ever takes place below 32°, if so low as this.

heat is sometimes sufficient, and the parent trusts partially to this, as is the case with the ostrich.

The eggs of the warm-blooded animals are very tender, and their vitality is destroyed by the cold of winter, whilst those of many others exhibit great tenacity of life, and survive not only the influence of cold, but also of extreme heat. They seem even capable of surviving the process of digestion, of entering into the blood and composition of the tissues, and of becoming afterwards developed, either in the body of the living animal or after its death.

Captain Franklin says, that on the shores of the Polar Seas (lat. 69° 30′, long. 140° 50′) when the thermometer rose to 45° they were tormented with mosquitos, and that they retired when it fell below this. The immediate activity of these and similar insects upon the beginning of warm weather, in regions where the temperature falls often to 50° and 60° below zero, and is below the freezing point during some portion of almost every day in the year, illustrates strongly the preservative powers of the vital principle both in the animals themselves and in their eggs or larvæ. They must of course exist in a frozen state at least eight or nine months, and many may, by being inclosed in masses of ice, escape the influence of the heat of summer, and thus remain congealed year after year. If one year in this condition does not destroy their vitality, there is no reason to suppose that a longer period will; and thus it is not impossible they may remain for centuries in a dormant state, and at length, if accidentally brought under the influence of a summer's sun, be roused to life and activity.

Moisture is another condition necessary to the activity of animal life. The vitality of the eggs of the higher animals and of the animals themselves is destroyed by drying. It is not so with the lower, nor with the seeds of plants, nor even with some plants themselves. The seeds of the Egyptian wheat have been found in mummies 3000 years old, and have germinated under the usual conditions. The snail has been restored to life after being perfectly dried; and many of the Radiata, especially the Infusoria, are capable of enduring the same state for an unlimited time.*

* This has been lately called in question, and extensive observations have

The influence of atmospheric air is also necessary to the development and activity of life. The seeds of many plants will remain dormant for years, if buried deeply in the earth, — probably for an indefinite period. Some animals are well known to retain life under the same condition. Frogs and toads have been found imbedded in stones or at a great depth in the earth, where they must have remained for ages; and have resumed their functions as soon as extricated from their captivity. This is probably equally true of animals lower in the scale, who have a much greater tenacity of life; and still more, of their eggs and larvæ. In these ways the ice of the polar regions and the materials of our globe may be full of animals or their embryos in this latent state, which only require to be exposed to heat, air, and moisture to assume all their appropriate functions.

It is a curious and interesting consideration, that in this way an animal whose active state is usually limited to a single season may have its existence protracted almost indefinitely. Still its period of positive activity is not probably extended, since, in the passive state to which it is reduced, there is a complete suspension of all its functions, and there is consequently no exhaustion of the powers by which life is maintained.

The instinct of animals is in no way more remarkably exhibited than in the provision they make for the well-being and support of their young, and this more among the lower than the higher. This instinct varies with their nature, and with the character of the offspring to be produced. In the common hen, it is at first an impulse which seems merely the result of a physical sensation, inducing her, after laying her eggs, to sit upon them patiently till the chick breaks the shell and utters its first cry. The moment this cry is heard it awakens a new sentiment, the maternal, the most tender and beautiful in nature. This impels her to leave her nest and search for food, and then for the first time she utters the peculiar call which her young so well understand. Till this

been made by competent naturalists with a view to determine it. Still, although doubt has been thrown upon the capacity of animals to survive the perfect and entire exclusion of water from their texture, it seems most probable that the retention of a very minute quantity is sufficient to prevent their destruction.

moment she appears to have no conception of the nature of the office in which she is engaged. She sits with the same assiduity upon an artificial egg, upon a stone, or upon an empty nest. It is not at any particular period that the maternal instinct is awakened, for if her eggs are removed or become addled, she remains brooding over her nest with the same untiring perseverance, for some weeks after her young should have made their appearance.

In insects, the blindness and at the same time the precision of this instinct is more strikingly exhibited. In some species the butterfly which lays the egg feeds upon flowers, whilst the worm that proceeds from it is carnivorous. But the parent places within its reach the food which its offspring needs, and not that upon which it is itself nourished.

A species of beetle, called, from its peculiar habits, the burying beetle, deposits its eggs in the dead bodies of animals which it afterwards buries, in order that its young when they leave the egg may have a supply of food. Their industry in accomplishing this is most remarkable. In the course of fifty days, four of them were observed to bury no less than twelve bodies, among which were two frogs and a linnet.

Even living animals do not escape the same fate. In the Mauritius, a traveller informs us that there is a large fly, something like the cantharides, who selects the cockroach as his victim, and fills its body with his eggs. A species of ichneumon deposits his progeny in the body of a caterpillar. The little grubs, when hatched, maintain themselves by sucking the juices and devouring the textures of the unfortunate victim, but carefully avoid all vital parts, so that he continues to live and feed as usual till he is about to pass into the chrysalis state. Then the little ichneumons leave him. He presents the appearance of an almost empty skin, and dies a caterpillar. In this case it is stated that the egg is deposited, not in any part proper to the caterpillar itself, but in the embryo butterfly already formed within, whose life is independent, and whose destruction, therefore, inflicts no injury upon the caterpillar.

The instinct of maternity, when in a state of activity, often produces, especially in the higher animals, a great change of character. The whole life and energies of the parent, — always of the female and in some cases of the male also, — are devoted to providing for and defending their young. The timid become bold, the weak powerful; whilst the courageous and strong become doubly ferocious and violent. The eagle will not hesitate to attack any animal, even man, that assails her nest, whilst every one knows how fearless and devoted is even the common fowl when its brood is in danger.* If we lift up a stone beneath which is a colony of ants, each one is seen at once to seize an embryo in its arms and scramble off to deposit it in a place of safety. The common earwig watches over its progeny as sedulously as the hen; broods over them, leads them forth, and collects them when scattered. The spider will defend its bag of young ones to the last extremity, and suffer itself to be destroyed rather than part with it. Some moths strip the down from themselves, "to defend from the winter's cold the brood which the insect mother will never see." The poppy-bee digs a hole about three inches deep, in shape like a Florence flask, lines it with the bright petals of the poppy, partly fills it with a mixture of pollen and honey, and in this magazine of food deposits her egg. In short, the whole history of animated nature is filled with similar examples of the wonders which this instinct is capable of performing.

But although so powerful in degree, this instinct is far from being discriminating or uniform in its operation. Some animals, as the hog and the rabbit, often devour their young. The common fowl, though so fierce in defence of her brood, is regardless of their safety in many other points, and will often carelessly trample them to death in her nest, or injure them by violence while scratching for food. She does not recognize the distinction

* "In the middle of June, 1821," says Dr. Richardson, "a pair of these birds [eagles] attacked me as I was climbing in the vicinity of their nest. They flew in circles uttering loud and harsh screams, and alternately stooping with such velocity that their motion through the air produced a loud rushing noise. They struck their claws within an inch or two of my head; and I endeavored, by keeping the barrel of my gun close to my cheek and suddenly elevating the muzzle when they were in the act of striking, to ascertain whether they had the power of instantaneously changing the direction of their rapid course, and found that they invariably rose above the obstacle, with the quickness of thought, showing equal acuteness of vision and power of motion."

between the progeny of her own eggs and those of a duck, turkey, or guinea-hen, but is equally attached to all. In the London Zoölogical Gardens, the egg of the great condor was placed under a hen, who hatched it after patiently waiting seven weeks and six days. She was as fond and careful of this strange nestling as if it had been one of her own species. A female buzzard in captivity was known for several years in succession to sit upon the eggs of the common fowl, to bring out full broods, and to rear them with the usual care; but when, on one occasion, to save her the tedium of confinement, a ready-hatched family was supplied her, she devoured them all. The maternal sentiment was prematurely invoked, the period of incubation being necessary to its development. There are instances among quadrupeds of a similar deviation, as of a cat who took under her protection a couple of foxes in connection with her own young, and another who performed the same office to a litter of rats.

Fishes in general take little care of their offspring. But in selecting places for the deposit of their eggs, they sometimes manifest great solicitude and skill. They make long journeys for this purpose, passing from the deep waters of the ocean to the shallows, and even migrating from salt water into fresh. The spawn is attached to pebbles, to rocks, to sea-weed, to leaves of plants, or is slightly buried in the sand, and then left to the mercy of the elements. The young when hatched swim about by themselves, and furnish food to the various inhabitants of the deep, sometimes even to their own parents. To this, however, there are some exceptions. The stickleback not only builds an elaborate nest of grass, sticks, straw, and stones, in which the spawn is deposited, but also guards the young after they are hatched, and protects them from destruction by other fish. This office, however, is wholly performed by the male. The female not only takes no part in it, but, after the eggs are deposited and the young come forth, is constantly seeking to devour them.

Among Insects the care of the young is for the most part confined to the preparation of a place of deposit for their eggs, and sometimes of food for the young after they make their appearance. In the social insects something more than this takes place, as in the bee and ant. It is a singular circumstance that the maternal instinct in these animals does not exist in those by whom the eggs are produced, — the queen bee and the female ant, — but in the neuters or workers. These have their entire charge, watch them constantly, attend them with the most assiduous care, and will even sacrifice life in their defence, till the young come forth; but their affection ceases with their office, and they manifest afterward the utmost indifference.

The formation of new animals by means of eggs is undoubtedly the most common but by no means the exclusive method of reproduction. Among some of the lower races, in addition to propagation by eggs, it takes place by means of buds as in plants. These are formed and nourished upon the body of the parent, and after arriving at a suitable stage of development are separated, and become distinct individuals. This is easily watched by the naked eye in the case of the common freshwater polype, an inhabitant of our ponds and ditches, and by the microscope in many Infusoria. Reproduction also occurs by a spontaneous process of division; one individual being converted into two equally perfect, each possessing all the parts and performing all the functions which belonged to the whole animal before their separation.

Closely connected with the reproduction of animals is the regeneration of parts which have been injured or lost, and also the formation of new animals as the result of artificial division. Even in the highest classes this capacity exists to a limited degree, as in the healing of wounds, the formation of a new bone, and, as has been alleged, the restoration of the lens of the eye, after its removal in the operation for cataract. Still it is among the lower races that it is most distinctly perceived. In the polypes, the arms when cut off are restored; and if the body be divided into a number of pieces, each will be developed into a perfect animal. When one of the rays of the starfish is lost or injured, a new one grows from the body. The earth-worm may be divided into several segments, each of which provides itself with a head and tail, and constitutes a new individual. In the planaria, a partial division of the body at either extremity terminates in the formation of an animal with two heads or two tails.

Crustacea and spiders reproduce claws and legs which they have lost; fishes their fins; and some of the reptiles their limbs, with bones, muscles, and nerves. Even so complex an organ as an eye has been restored to the water-newt.

The changes which attend the development of a new animal in the egg do not cease when it is ushered into the external world. They continue to take place through a considerable part of its existence. In some species, as in man and the higher classes, there is still retained the same general form, mode of life, food, and residence; whilst in others, lower in the scale of being, transformations and variations occur to such an extent that the individual at one period of its existence presents a form, a structure, and functions so different from that which it presents at another, that it has been even taken for a creature of a different class.

Were we able to examine man at only the two extremities of his period of development, with no knowledge whatever of the gradual change which has in the mean time taken place, we should hardly recognize him as the same being. Differences no greater between the young and old of some animals where no such opportunity has been afforded, have led to their being regarded as distinct species. But the variations which chiefly interest the student of natural history, though probably a result of some one great and universal law of development which also covers the changes just alluded to, are of a more marked and abrupt character, and involve greater departures from the form and habits presented at birth. The most interesting examples of these are furnished by the transformations of animals of the frog kind, by the metamorphoses of insects, and by what has been called the alternate generation of animals.

Every one is familiar with the appearance of the frog when it is first noticed in the waters of ponds, ditches, and rivers, after being hatched in the spring, — a small, round, black body, with a large head, and a tail of considerable length adapted for swimming, without limbs, moving, living, and breathing by gills, like a fish. After a certain period passed in this state, a series of changes takes place: the hind legs sprout out at the base of the tail, at a subsequent period the fore legs also make their appearance, and the tail wastes and disappears. Contemporaneously, the organs of respiration are undergoing an important modification. The lungs are developed and the gills gradually become incapable of their function, till the animal can breathe only air. It is no longer capable of the life of the fish, and, though still in some sense aquatic in its habits, it must come occasionally to the surface of the water, or upon the land, in order to carry on respiration.

In many insects, when the egg is hatched, an animal comes forth differing as entirely from its parent as a serpent from a bird. It leads an entirely different life. It inhabits sometimes the water, sometimes the earth. It infests leaves, fruits, the bodies of animals. It is called variously a maggot, a worm, a caterpillar. Its range of motion, of sensation, and of function is extremely limited. It seems indeed to live but to feed and grow, it has no sexual character, and, even if living in a community with others of the same species, it has little or no distinct association with its kind. After a definite period, it passes into a condition in which all indications of external activity are suspended. Enveloped in a new covering of its own manufacture, its mode of existence is not unlike that which it passed within the egg. It lives, and in a limited degree breathes; but it does not feed. Still, important changes are going on within. A new animal is forming. During this second incubation, as it may well be called, as in the first, the materials which have been gathered together during its previous life are employed in the construction or development of another organism. At the appropriate period, active life again returns. A creature comes forth endowed with a different nature. It went into its place of seclusion one of the most unsightly and disgusting of living things. It issues from it one of the most gay and beautiful. It then crept slowly and feebly upon the earth. It now floats gracefully through the air. Its form, its food, its residence, its instincts, have all undergone a radical change. This wonderful transformation has always attracted, more than any phenomenon in nature, the admiration of mankind. It has been looked upon as an emblem of the double destiny of our race; the worm, of our bodies crawling painfully through a sordid existence to the tomb; the perfect insect, of our souls springing from it to the inheritance of a higher life.

There are still other transformations, less common, and less within the limits of common observation, which are equally curious and worthy of attention. They have sometimes been regarded as rather indicating a mode of reproduction, than of a metamorphosis. They seem, however, to be upon the whole more analogous to the latter than to the former. The first individual in the series is the product of an egg, but it does not, in its turn, produce an egg. It gives origin, by the process of budding already referred to, to an offspring entirely different from itself. At the next step, however, reproduction takes place by the egg in the ordinary way, and so on alternately. It is as if the child resembled not its parent but its grandparent. This is the simplest and most limited form of the process. In other cases it is more complicated, and the number of generations is greater. This happens with the aphides or plant-lice, among whom it is sometimes the eighth or ninth before the original type returns. It is to be remarked as an important circumstance indicating the true character of these phenomena, that, as happens also in the metamorphosis of the frog and the caterpillar, it is only in a single generation that the distinction of sex and the production of eggs takes place. It is in this therefore only that the animal is to be regarded as in its perfect state; in the others as only in one of the stages of its progress toward it.

We perceive a certain analogy between these phenomena and some which are not infrequently observed in tracing the hereditary transmission of physical conditions in families of our own species and of the animals near us in the scale of being. It often happens that some peculiarity of structure, of feature, or of color, or some disease belonging to an individual, will vanish in his child, and perhaps in his grandchild, but reappear in the succeeding generation. All these curious phenomena may be connected with some real but hidden law of relation of parent to offspring, exhibiting itself in different ways according to circumstances, in different branches and classes of the animal kingdom.

CHAPTER X. (W.)

DISTRIBUTION OF ANIMALS. — COVERING, MIGRATION, AND HYBERNATION.

It seems probable that every species of animals was originally created in, and fitted to inhabit, some particular district of the earth. Here the individuals belonging to it are most numerous. As we depart from it they become more rare, till at last they vanish altogether. The space over which they are distributed will be more or less extensive according to their peculiar character and their power of accommodating themselves to varieties of food, climate, soil, and situation.

Still many animals, though thus found to exist in a natural state only within certain limits, are capable of a wider range, and, upon being removed by design or by accident, will continue to exist in other districts. In this way most of them have been successfully kept in public institutions. A few are capable of enduring all climates, as man and the dog; but in order to this they either avail themselves of artificial means of protection, or undergo certain physical changes. In general, natives of temperate countries, where there is a regular alternation of seasons, are capable of accommodating themselves to a greater variety of climate than those of either the frozen or the tropical regions. Thus the horse, the ass, and the sheep have generally accompanied man, though not so universally as the dog; but the orang-outang cannot long endure even the mild winters of the south of Europe, and the reindeer languishes, sickens, and dies, if far removed from his native cold.

Every country had then originally its peculiar animals, and they become diffused over extensive regions only so far as they are able to accommodate themselves to the changes which such a diffusion requires. Upon setting foot in America, its discoverers found themselves at once in the midst of a living creation whose features were new to them; and whenever we hear of the discovery of a new country, we expect to learn, in the sequel, of the discovery also of new species of animals. So well settled is this, that no expedition for the survey of unknown parts of the globe is regarded as complete, unless accompanied by professed naturalists to observe and record the novelties they are sure to meet.

It belongs to a specific treatise on Natural History to enter into a detailed examination of this subject. But of the general fact the proofs are obvious and striking. To the two great divisions of the earth, the Eastern and Western continents, there are few if any animals in common, except at their northern extremities, where their near approach to each other, and their possible communication by means of ice, may have enabled those whose original centre was in the one, to pass over and propagate themselves upon the other. The more remarkable species in the Old World, the elephant, rhinoceros, hippopotamus, camelopard, and camel, are not only wanting in the New, but there are even none properly corresponding to them among living races, in their general form and character. Of the celebrated carnivorous animals, the lion, tiger, &c., there are none which equal the Eastern in size, strength, and ferocity. The bison of America is a different animal from the buffalo of the other side of the Atlantic, though called by the same name, and the monkeys, though resembling those of the Old World in general form, character, and disposition, are yet distinguished by physical characteristics which leave no doubt of their being a different race. As there are animals in the East which do not correspond to any of those in the West, so the West has also its peculiar races, — the sloths, the armadillos, the anteaters, and a few Marsupials.

In regard to the Mammalia, it appears to be mainly true that those of the Old World are more noble, and, when domesticated, more useful to mankind, than any in the New, and that the average of size in the former is above that of the latter. This was at one time supposed to justify the conclusion, that the climate and soil of America were less favorable to the development of animal life than that of Europe and Asia, and that the European race of man himself was likely to deteriorate when transplanted to these new regions. But beside the fact that man and the domestic animals, under circumstances equally favorable, have not deteriorated in America, an examination of the other classes is sufficient to show that this inferiority is not owing to any general causes which exercise an unfavorable influence upon living things. The Birds, Reptiles, and Fishes of our continent are at least equal to those of the other, whilst Insects are alleged to be larger, more numerous, and more beautiful.

The continent of Australia presents even more remarkable differences in the character of its Mammalia, than those which were found to exist on the discovery of America. They are not only distinct, but as much inferior in size and useful qualities to those of America, as these are to those of Europe. There is not one exceeding the dog in size, and they seem to have been created upon a somewhat different model, though the same great plan has still been adhered to.

Every animal has thus been originally placed upon such a portion of the globe as is best adapted to its structure, its character, and its wants. But even in the same situation, the physical influences to which it is exposed are not at all times the same, and, especially in cold and temperate climates, it is subjected to great extremes of temperature. At the same time, during a longer or shorter period of the year, the supply of food for many herbivorous species is cut off, and that of the carnivorous essentially diminished. The disastrous effect of these causes is obviated in several ways. Those animals whose food continues to be found through the winter months, or who are able to lay up a stock of provisions for their support, are protected against the injurious effects of cold, by a change in the quantity, quality, and color of their usual covering. Of those not thus provided for, a part migrate to warmer latitudes, and a part fall into a torpid condition, and pass the winter in what is denominated a state of hybernation.

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1. *Of the Covering of Animals.*

In proportion as countries are colder, animals residing in them are more thickly clothed by some non-conducting substance, usually hair, wool, or feathers. As we approach the tropics this becomes thinner, till in some cases it vanishes almost entirely, and the skin is left nearly naked. In marine animals, so numerous in the arctic regions, this provision would not answer, since the same material which might well serve for an animal on land, would be inconvenient to one which inhabits the water. Instead, therefore, of a non-conducting protector upon the outside of the skin, Nature provides one underneath it, in the form of a thick layer of fat.

The same difference which is required between the clothing of the inhabitants of the polar and equatorial regions, is equally necessary between the summer and winter clothing of those of the temperate. It undergoes a change to correspond with the seasons. It becomes thicker upon the approach of winter. It is thicker in the higher latitudes than in the lower. In the same latitude it is more abundant in a severe winter than in a mild one. It is produced sooner in an early winter than in a late one; and even a few days of unseasonably cold weather, in the early autumn, will sensibly promote its growth.

Changes of color are not so common or important; yet, in cold climates, there are many instances of a complete change from a dark color to a white, both of fur and plumage, on the approach of winter. In summer, the Alpine hare is of a tawny gray; in winter, of a snowy white. The ermine, whose summer dress is of a pale, reddish brown, undergoes a similar alteration. In the color of many birds the same change is observed, as in a great variety of those small species known as snow-birds.

The effect of this, in protecting against cold, depends upon the known laws of the transmission of heat. A dark body imparts its heat to the atmosphere more rapidly than a light one, when the atmosphere is *cooler than the body*. We know, though we suffer from heat in summer and from cold in winter, that under all ordinary circumstances the atmosphere is colder than our bodies. In summer we need provisions which will aid us in parting with our heat, and in winter those which will aid us in preserving it. A dark covering favors the radiation of heat, a white one prevents it; hence the former is the best for summer, and the latter for winter. The black skin of the African is best for those who are exposed to the heat of a perpetual summer; and the light complexion of the northern races of Europe for those whose winter is long and cold.

This is true wherever the temperature is less than that of the body, and the atmosphere *itself* is seldom otherwise for any length of time. But the sun's rays are usually hotter than the atmosphere, and when exposed to them, the effects of color will be reversed. This seems inconsistent with the fact that the black races endure toil under the sun's rays better than the white. It is explained, however, by the consideration that the skin of the African, from its great oily secretion, reflects heat largely, and that there exists a peculiar power in dark-colored surfaces of modifying the rays which they absorb, so as not to produce that effect upon the living textures which their temperature would lead us to expect.

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2. *Of the Migration of Animals.*

The second method by which certain animals avoid the dangers and sufferings of the cold season is by a periodical migration. This, so far as it is intended to answer this specific purpose, takes place chiefly, if not wholly, among Birds.

In most districts there are some birds which depart on the approach of winter to return in the spring; there are others which make their appearance only in winter; whilst some are constant residents. These constitute three classes, winter birds of passage, summer birds of passage, and resident birds.

The period of the arrival of the winter birds of passage varies with each species, and corresponds to that at which the advance of the season develops the kind of vegetable or animal which furnishes its appropriate food. From the latter end of March to the middle or end of May, there is a constant succession of fresh arrivals. Mr. Wilson calculated that during this period no less than a hundred millions of individuals entered the State of Pennsylvania. In a single garden of eight acres, the nests of fifty-one pairs were detected and counted.

The same species is not migratory under all circumstances. The American mocking-bird is a resident of the Southern States, but in the Northern, is a summer bird of passage. The quail, as it is called in the Northern States, or partridge, as denominated by naturalists, is resident in New England, but migratory in regions further north; hence in severe winters it is driven from its colder haunts, and appears with us in unusual numbers.

Of birds which ordinarily migrate, a few sometimes remain through the winter; such are the common robin and many woodpeckers; indicating that it is not cold only, but failure of food, which renders migration necessary.

The period of migration varies with the early or late advance of the season. A few warm days even in February will bring forward several species, just as it causes the buds of plants and trees to swell prematurely. On the return of cold, they again disappear. With regard to many birds, their migration is not a continued flight from the extreme southern to their extreme northern residence. They dally on their way. They follow the opening spring, and make the journey toward their summer quarters with greater or less rapidity, according to the advance of the season and the supply of food. If, after going forward a few hundred miles on the occurrence of warm weather, it becomes cold again, they retrace their path, and a few hours' flight brings them back to a more congenial atmosphere. If they find in any spot an abundant supply of food, they delay there an unusual period; and for this purpose, during their journey in each direction, they are observed to make a visit of days and sometimes of weeks in a particular locality.

An example of this dilatory migration is afforded in one of the most interesting of birds, the bobolink of the Northern, the reed-bird or bunting of the Middle, and the rice-bird of the Southern States. His winter residence is probably in the central parts of the continent from Mexico to the river Amazon, and perhaps even further south. At the end of April he first enters the United States, and in the beginning of May visits the neighborhood of Savannah. In a week more he is seen in Pennsylvania, making a continuous journey, and delaying but a short time in Virginia to feast upon the green ears of wheat and barley. After a week's sojourn in Pennsylvania he leaves for more northern quarters, and speedily appears in the northern

States. Here he makes his home for the season, builds his nest, and rears his brood; but not here alone, for he is found over the whole country from New York to the mouth of the St. Lawrence, and thence around by the Lakes to the Illinois. As the season advances, the plumage of the male changes and the whole tribe assume the same colors. Hence it was for a long time supposed, in those districts through which they passed on their way south, that none but females returned from their summer quarters. By the middle of August they begin their return. For two months they remain in Pennsylvania, feeding upon the seeds of the reed, which they find there in great abundance, and upon which they grow very fat. As the nights become cold, they make a second remove, and descend upon the rice-fields of the South, where they commit great depredation.

The gradual passage of other birds has been noted by naturalists. The purple martin arrives in Savannah by the first of March; in Philadelphia not till the latter part of the month. The cat-bird moves more slowly still to the North. The whippoorwill is often heard for a few nights in the spring at some particular spot; but no more till, on his return in autumn, he revisits his old haunts, and his melancholy notes are again heard a few more evenings before leaving for the South.

We are very familiar with many of our summer birds of passage, as the thrasher, woodpecker, bluebird, humming-bird, &c.; but, as we are less accustomed to the open fields in the cold season, those of the winter pass without our notice. There are, however, large flocks of small birds of various sizes and colors, which fly around farm-houses and barns, and are particularly lively before storms of snow and rain. By extreme cold or great depth of snow, they are often driven to seek refuge and food in the streets of cities. They are known under the common denomination of snow-birds. They include, however, several distinct species. One of these is the snow-sparrow, found very extensively over the whole continent of North America, from the Arctic Circle to the Gulf of Mexico, and from the Atlantic to the Pacific Ocean. In the New England States they reside from October to April. Their early appearance indicates a severe, or at least an early, winter, because it is produced by premature coldness of the season in the countries where they have passed the summer. In periods of extreme cold, especially when the snow is unusually deep, they are driven in search of food to the neighborhood of human habitations, and become very familiar. In April they depart for the North, have been observed in June at Hudson's Bay, and at a still later period arrive in their extreme northern retreats.

The snow-bunting is another remarkable winter bird. It is common to both continents, and is known in Europe from the extreme northern countries to the fiftieth degree of latitude. They rear their young only in the coldest regions, particularly in Greenland and Spitzbergen, where they are found in vast numbers, and are often preserved in a dried state for winter's food. Upon the approach of winter they retreat to the South, but never seem to require any milder season than that of a moderate winter; and in America, on account of the severity of our seasons as compared with those of Europe, they penetrate to a more southern latitude.

The migrations which have been enumerated are made for the most part in short and interrupted journeys. But there are other birds capable of long flights, whose migrations are far more remarkable. Such are the Waders and the Web-footed. Of these the most universally known are the common wild geese. With their movements we are familiar from childhood, as indicating on the one hand the approach of winter, and on the other the return of spring. They move in regular order, sometimes in a single line, sometimes in two lines converging to an angle. Where they terminate their flight in either direction is not certainly known. A few, on their southern journey, remain behind in some of the secluded bays and rivers of the United States, particularly in New Jersey; but the main body passes on, it is not known where. The limits of their northern journey are equally uncertain. At the Lakes and at Hudson's Bay they are still seen passing on to the North. They were seen by Hearne within the Arctic Circle, still tending toward the Pole; and Captain Phipps saw them feeding at Spitzbergen, in the latitude of 80°.

If there be, as late explorations render it probable, an open polar sea, its shores and islands are likely to be the summer residence of this and many other migratory species. The constant and equal influence of the sun for six months in succession may very probably produce at least as favorable a season as its oblique revolutions in the latitudes somewhat lower. In this remote region, undisturbed by man, surrounded by an abundance of food, they may bask in the uninterrupted sunshine of a polar summer, lay their eggs, and rear their young. As soon, however, as this task is completed and they tend toward winter quarters, this security is at an end. Their flight is like the march of an army through an enemy's country. Everywhere the excellence of their flesh as food makes them most valuable prey. At Hudson's Bay they constitute an article of no small importance, and they are destroyed in vast numbers and preserved for use. A single sportsman will frequently kill two or three hundred in the course of a day.

The swallows also perform very extensive migrations. It was formerly a common belief that these beautiful birds passed the winter in a state of torpidity in the banks of rivers, the hollows of decayed trees, the recesses of old buildings, and even imbedded in mud. That some individuals have been occasionally found in a torpid state and have revived on exposure to warmth, is perhaps true. There is, however, the best reason for believing that these are exceptional cases, and that an immense proportion migrate to a warmer climate. There has been some uncertainty as to the regions whither they betake themselves. Those of Great Britain have been traced to Africa, whilst those of the United States have been supposed to make their way, among other places, to Honduras, where they are found in abundance from October to February.

Birds which perform short and gradual migrations generally move in small and detached bodies; those which perform long ones assemble in groups and set out in large companies. This is particularly the case with swallows. Before our country was so fully settled, their collections for this purpose were more frequently noticed. They were in the habit of selecting large hollow trees for their place of rendezvous, and here they assembled and remained in company for several days before beginning their annual journey. By those who witnessed their movements, they are described as issuing in the morning from this place of retirement in countless numbers, rising up into the air like a column of smoke, and dispersing in all quarters. At night, they returned a short time before the hour of rest, filling the air in every direction, and flitting about as thickly as a swarm of insects in the summer's sun. After a while they suddenly united themselves into a regular body, and entered into their hiding-place with immense rapidity, pouring into it like a stream of water.

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3. *Torpidity, or Hybernation, of Animals.*

The third method by which animals are enabled to escape the effects of the cold of winter, is by passing into a state of *torpidity.* This state bears a considerable resemblance to sleep, and has been sometimes confounded with it. It is, however, a different condition; and yet a slight degree of torpidity is not very different from a very sound and prolonged sleep.

Torpidity answers, in another way, the same purpose to those animals who pass into this condition, that migration does to birds. Birds avoid the winter's cold and scarcity by flying to a *country* where they are sure of adequate warmth and food. Quadrupeds effect the same purpose by passing into a *state* in which they require less of these necessities of life. The time of going into winter-quarters depends upon climate and season. In England it is later than in Scotland; in the United States, later than in Canada. Animals that in New England are torpid from October to April, would in Canada pass into this condition in September and revive in May.

The number of quadrupeds that hybernate, or pass into the torpid state, is much smaller than of birds that migrate. The hybernating animals are of those genera that have claws, never of those that have hoofs. A few belong to the Carnivorous tribes, as the bat, the tenrec, the hedgehog; the greater part to the Rodentia or Gnawers, as the marmot, hamster, jerboa, dormouse, prairie-dog, and woodchuck.

Their position is the same as in ordinary sleep. The body is bent forward upon itself almost into a ball, the head, legs, and tail being all gathered up together under the abdomen. In this way the animal heat is best preserved, especially in the extremities, parts most liable to suffer from its loss. Species that are solitary in their ordinary habits do not associate in the dormant state, as the hedgehog and dormouse ; those that usually live in societies, associate also in the winter, and avail themselves of one another's warmth. Bats, for example, congregate in large numbers, and suspend themselves in clusters like a swarm of bees.

As beasts and birds of prey are on the alert all winter, animals select such places for their winter's retreat as will secure them from their attacks. Bats immure themselves in caverns, in the vaults of old castles, and in chimneys; the dormouse seeks a hollow tree, the hedgehog its nest of leaves; the woodchuck, jerboa, marmot, and hamster retreat to their burrows. A Canadian jerboa was once disinterred, coiled up in the midst of a ball of earth and clay twenty inches under ground. He was completely torpid when discovered, but speedily revived on exposure to a gentle heat.

Torpidity is not equally complete in all cases. Some species accumulate a stock of food, and rouse up occasionally, on the occurrence of a few warm days, to partake of it. Still there is, to a greater or less degree, an intermission or suspension of the important functions of life. The respiration is less in amount, and performed at longer intervals than in the natural state. The circulation is diminished, and the temperature of the body falls.

When the torpid state is most complete, the animal feels stiff, and cold like a reptile. It would at first be supposed dead, for no distinct signs of life are at once obvious. When torn or mangled, it manifests no feeling except by an occasional gasp. The temperature of a hedgehog in summer, with the air at 78°, was 97° or 98°. In the torpid state, with the air at 44°, it was only 48°. The natural temperature of the greater number of small animals is a little above that of mankind, varying from 98° to 104°. In the dormant state it falls to 45°, to 40°, and sometimes even as low as 36°.

The efforts of the lungs are less frequent, and are sometimes intermittent. The marmot in its ordinary state makes five hundred respirations in an hour; when torpid, these are reduced to fifteen. Sometimes a number of respirations are made in rapid succession, and they then cease for a considerable interval. The respiration varies with the degree of cold. During mild weather it is increased; when colder, diminished; and when extremely severe, it is for a time entirely suspended. Spallanzani placed some dormice, at the temperature of 32°, in receivers containing respectively carbonic acid gas, hydrogen, and azote, over mercury. They remained in them three hours, and then, on exposure to warmth, revived and began to breathe. The suspension of respiration in this case prevented the usually injurious effect of these gases; for, when a slight warmth had somewhat revived the animals, and the respiration was partially performed, the experiment was fatal.

The heart also becomes slower and feebler in its pulsations, and often intermittent. In a dormouse, the pulse is naturally so rapid as to be counted with difficulty; but, as he passes into the torpid state, it falls in number to eighty, to sixty, and so downward to sixteen in the minute.

Although cold is not the only evil against which torpidity is intended to provide, yet this seems to be brought on by the direct influence of temperature. If an animal at its usual period of hybernation be kept warm, it will be preserved from it. If, after becoming torpid, it be carried into a warm atmosphere, it revives, whilst a fresh exposure to cold again renders it dormant. Animals which in one climate find hybernation necessary for their safety, in a warmer are able to dispense with it. The common woodchuck, or ground-hog, hybernates in the Northern States; but at the South it passes the winter in its natural condition. It is also true of a variety of other species, both on the Old Continent and the New, that they hybernate at the North, but not at the South.

The state of torpidity may be prevented in animals disposed to it by confining them in apartments artificially heated; but, even in this case, they exhibit at particular periods a strong tendency to fall into it. There are many differences in the details of this condition, which may be illustrated by particular examples. The dormouse becomes easily torpid, but does not constantly remain so, frequently awaking to take a little food. It is a very fat animal, and does not entirely lose its flesh during its hybernation. The marmots, a species allied to the common wood-chuck, inhabit the colder regions of the Alps and Pyrenees. In them the torpid state is much more complete, and of longer duration, continuing from the end of September to the beginning or middle of April. The burrow in which they reside is prepared with much labor and sagacity. It varies in length from eight to twenty feet. It is divided into two passages: a lower one, intended as a drain to carry off the water which enters from rain or melting snow; and an upper, terminating in a large circular chamber with an arched, oven-shaped roof, from three to seven feet in diameter. This is, during summer, lined with an abundance of soft dried grass, and here the winter is passed. On the approach of cold weather, the tenants of the burrow resort to it, close up its entrance with earth, stones, and hay, collect themselves into a heap, each individual being rolled up in the manner just described, and exhibit no visible signs of life till spring. They go into their winter's retreat quite fat; they come out much emaciated.

The hybernation of the hamster, which inhabits some of the northern countries of Europe, does not essentially differ from that just described. He does not, however, pass immediately into a dormant state, but, having retired to his apartments, and closed them, remains for some weeks awake, feeding moderately upon a stock of provisions which he has accumulated. It is only during the severest portion of the winter that he becomes completely torpid; for in the spring he rouses himself some time before he dares to venture abroad, and again takes food.

The torpid state, then, is not chiefly intended to enable animals to endure a great degree of cold with impunity; its principal and ultimate object is rather to aid them in maintaining life, through that season in which their natural food is wanting, without suffering from starvation. In the active state of their bodily functions, the long privation of food which they must undergo would necessarily prove fatal; in the dormant state they endure it with impunity. A certain degree of cold is the exciting cause of the state of hybernation, but this is its primary object. It is, in fact, not only a long sleep, but a long fast. So far is it from its being the primary object to enable animals to endure cold, that an increase of cold beyond a certain point rouses them from it. There is a range of temperature within which torpidity continues; but, as soon as it becomes either colder or warmer, it ceases. Animals become torpid, for instance, at from about 45° to 55°. If the cold exceed this, at first their lethargy is more profound; but, soon after the thermometer has fallen much below the freezing point, they are roused by it. A hedgehog, when first exposed to the atmosphere at 26°, slept very soundly, and his temperature fell to 30°; but, after this had continued a couple of days, the heat of his body had risen to 93°, and he was awake and moving about. A marmot that had been torpid at 45°, being suddenly exposed to a cold of 16°, soon revived, moved about, shivered, and tried to escape, but was finally frozen to death.

This is a most curious and interesting provision, and strikingly illustrates the purpose for which this condition is induced. The ordinary cold of winter produces torpidity, but does not endanger life; the extraordinary, if continued, would cause death, and consequently it rouses the animal in order to give him a chance to escape the impending danger. Except for this arrangement, those periods of extraordinary severity to which every climate is liable might prove fatal to large numbers of hybernating animals. A similar phenomenon has been observed among bees. During extremely cold weather the heat of their hives rises to 82°, a degree far above its average, and these insects are all in a state of commotion, running to and fro, and exercising their wings with great activity, as if to prevent the pernicious effects of cold.

Animals come out of the torpid state lean, but not always greatly emaciated. There are no indications of exhaustion; on the contrary they apply themselves to their usual pursuits with renewed energy. It is not improbable, indeed, that this annual repose is required by the constitution of some animals in certain climates, in the same way that sleep is daily demanded by that of all; and that cold will not produce it where this necessity of the system does not exist. A hedgehog, when exposed in summer to the same temperature as that which produces torpidity in winter, manifested no tendency to that state. He exhibited marks of great distress, and for a while resisted the influence of the cold, but was finally destroyed by it.

The first stage of torpidity in animals is probably very like that lethargic state into which men fall who are exposed to a very low temperature, and which, if indulged in, terminates in a condition whence they cannot be aroused, but perish in it from cold. This state is described as not attended by distress, but on the contrary as a sort of soothing languor, extremely difficult to resist. Dr. Solander, who accompanied Captain Cook in one of his voyages, came near perishing by yielding to it, although so perfectly aware of its nature and its danger that he had previously been warning his companions against it. In his late voyage to the arctic regions, Dr. Kane describes the influence of the same condition; and he found that, by a few moments' indulgence in sleep, the strength and spirits were much refreshed. There are many facts seeming to show, that in this state both men and animals to whom the state of torpidity is not natural are capable of resisting the influence of cold longer than if they kept awake. In accordance with this law, sheep especially have been known to survive a long time while buried under banks of snow.

Among the lower classes the state of torpidity is more universal and complete, and they are capable under its influence of enduring much greater degrees of cold. Many of them do not breathe, circulate, or digest at all. Some reptiles, as tortoises and frogs, dive beneath the mud of ponds and rivers; lizards and serpents retire to their holes, to the crevices of rocks, and to trunks of trees. If the cold be indefinitely continued, they seem capable of continuing torpid an indefinite time. Spallanzani kept toads and salamanders in an icehouse for three years, during which they exhibited no signs of life. At the end of this time, on exposure to warmth, they revived. Fishes have been often noticed to revive after being completely frozen; and, in cold latitudes, it is not improbable that the smaller species inhabiting shallow waters may thus continue in a state of torpidity for months. Among insects and the less perfect animals, this state is still more easily induced, continues longer, and is more complete.

In some parts of the world, the snail has been observed to take precautions against cold, which are worthy of note from their resemblance to one of our own expedients. When cold weather begins, it closes the opening to its shell by a thin partition of a glutinous substance, which when dry becomes hard. As the season advances, it constructs a succession of these at small distances from each other, leaving a stratum of air between each two; in this way imitating the double windows which are found so effectual a security in our own habitations.

Deprivation of moisture has the same effect, upon certain animals, to bring on a suspension of their active lives, that simple cold has upon others. Many of them may thus be made to pass into the torpid state, and to remain in it for a long time. A case is related, apparently upon good authority, of the preservation of some snails in a dried state for fifteen years, at the end of which time, upon the application of moisture, they revived. There can be no doubt that many Zoöphytes, as well as Insects, are enabled to endure a suspension of all the ordinary functions for an indefinite time, either by cold or by dryness.

A specimen of an insect (*Buprestis splendens*), full of strength and vigor, was once observed extricating itself from the wood of a desk in which it had been imbedded twenty-two years. This was known from the length of time the desk had been in use.

Five specimens of a green toad were once found in the centre of a tree nineteen inches in diameter. Every exertion was made to discover a communication between the external air and the cavity, but without success. Every part of it was probed with care, and water kept in each half for a considerable time, without its passing into the wood. The adjoining wood, for half an inch from the cavity, appeared as if charred. These reptiles when discovered appeared to be dead, but under the influence of a warm sun were soon restored to animation.

In January, 1845, while engaged in mining at a depth of forty-five feet, a workman disinterred a frog which was embedded in a piece of shale. It appeared at first quite weak, and could only move with difficulty. Its eyes were of the natural size and appearance, but it could not see; there was a fissure or line in the place of the mouth, but this could not be opened; and there was a deformity in its spine which had assumed an angular shape corresponding to that of the cavity in which it had been confined. It continued to increase in size and weight, though incapable of taking food, and was able to breathe only through the thin skin covering its under jaw. Narratives of this kind, though given upon what is apparently good authority, should be received with much caution. Although they may be given in good faith, there is no absolute assurance of the competency of the observers, or of their having taken into consideration all the circumstances necessary to establish facts intrinsically so improbable.

The same remark is applicable to the following narrative of the alleged torpidity of one of the human species. It is taken from an account given by Sir Claude Wade, a British political resident at the court of Runjeet Singh, in Lahore, in 1837. Sir Claude was an eye-witness of the disinterment of the individual concerned, and his character renders the idea of the invention of the story by him very improbable. The case was that of a fakir who was buried for the space of forty days, and lay during that period as insensible as if dead. Sir Claude did not witness the interment of the body, having arrived a few hours after it took place; but he had the testimony of Runjeet Singh himself and the most credible witnesses of the court to the fact; and the disinterment took place under circumstances which, in his opinion, rendered any deception impossible. The body had been deposited in a square building, consisting of a closed room in the middle, with a verandah all around. There had been an open door on each side; three of these had been closed up with brick and mortar, the fourth with mud up to the padlock, and this was sealed with the private seal of the prince. There was no aperture by which air or food could have been admitted. The place had been constantly guarded by four sentries, and been regularly visited by order of Runjeet Singh, who was himself skeptical as to the reality of the phenomenon. The body, tied up in a linen bag, which had become mildewed, was found in a cell three feet below the level of the floor, in a wooden box, upon which was also a padlock sealed like the other. There was no sign of life except some heat about the head. The body was bathed in warm water, plugs of cotton and wax, with which the nostrils and ears had been filled, were taken out; and after a variety of other appliances the fakir began to revive, and in the course of an hour was able to talk with those about him freely, though feebly. It would require additional observation to produce perfect conviction of the reality of this long suspension of animation; yet the evidence is such as would be satisfactory in any case where the facts were of a less extraordinary character.

The attention of observers has been chiefly directed to the means provided for the protection of animals against cold. For the most part, there is in no portion of the earth such continued heat as requires any other provision for protection against it, than that power of regulating their own temperature which is possessed by all animals. But to this there are exceptions. In some tropical regions, during certain seasons of continued heat and dryness, many animals pass into a condition analogous to hybernation, called æstivation. Of this, the most trustworthy account has been given by Tennent, in his account of the island of Ceylon. As the alligator becomes torpid from cold, the crocodile does so from heat and dryness, and is found deeply embedded in the mud and clay at the bottom of tanks from which all the water has been drawn by evaporation. During the dry season several kinds of Fishes pass into the same condition, and are found under the same circumstances. They are dug up from beneath the clay of dried rivers, and this at considerable depths. In Abyssinia they have been found at a depth of six feet. Even some of the Mammalia pass into the same condition, when heat and dryness cut off their supply of food; thus the tenrec æstivates in Madagascar, as its allied species, the hedgehog, hybernates in Europe. Probably it is less the heat to which this result is to be attributed, than the dryness that results from it, and the consequent lack of food. Fishes, as we are informed by Dr. Richardson, remain frozen for a long time in the shallow waters of the polar regions, and revive when thawed, — surviving thus a long suspension of circulation and respiration. A similar suspension must take place when they are buried in heated clay; and the preservation of life is in this case a more remarkable phenomenon, since, in addition to the suspension of these functions, there is an exposure to influences whose tendency is to produce decomposition.

CHAPTER XI. (S.)

OF THE HABITATIONS OF ANIMALS.

Of the quadrupeds that make or choose habitations for themselves, some dig holes in the earth, some take refuge in the cavities of decayed trees, and in the clefts of rocks, and some actually construct cabins or houses. But the artifices they employ, the materials they use, and the situations they select, are so various and so numerous, that our plan necessarily limits us to a few of the more curious examples.

The Alpine Marmot is a quadruped about sixteen inches in length, and has a short tail. In figure, the marmots have some resemblance both to the rat and to the bear. They delight in the regions of frost and of snow, and are only to be found on the tops of high mountains. Their retreats are formed with much art and precaution. With their feet and claws, which are admirably adapted to the purpose, they dig the earth with amazing quickness, and throw it behind them. They do not make a simple hole, or a straight or winding tube, but a kind of gallery somewhat in the form of a Y, placed thus ≻, each branch of which has an aperture, and both terminate in a capacious apartment. This innermost apartment alone is horizontal. Both branches of the Y are inclined. One of them leads downward from the apartment, and follows the declivity of the mountain. This branch is a kind of aqueduct, and receives and carries off the filth of their habitations; the other, which rises above the principal apartment, is used for coming in and going out. The place of their abode is well lined with moss and hay, of which they lay up great store during the summer. They are social animals. Several of them live together, and work in common when forming their habitations. Thither they retire during rain, or upon the approach of danger. One of them stands sentinel upon a rock, while the others gambol upon the grass, or are employed in cutting it, in order to make hay. If the sentinel perceives a man, an eagle, a dog, or other dangerous animal, he alarms his companions by a loud whistle, and is himself the last that enters the hole.

In places much frequented by man, the Beavers neither associate nor build habitations. But in the northern regions of both continents, they assemble in the month of June or July, for the purpose of uniting into a society, and of building a city. From all quarters they arrive in numbers, and soon form a troop of two or three hundred. The place of rendezvous is generally the situation fixed upon for their establishment, and it is always on the banks of waters. If the waters be flat, and seldom rise above their ordinary level, as in lakes, the beavers make no bank or dam. But in rivers or brooks, where the water is subject to risings and fallings, they build a bank, which traverses the river from one side to the other, and is often from eighty to a hundred feet long, by ten to twelve broad at the base. The part of the river where they erect this bank is generally shallow. If they find on the margin a large tree which can be made to fall into the river, they begin, by cutting it down, to form the principal basis of their work. This tree is often thicker than a man's body. By gnawing it at the bottom with their four cutting teeth, they in a short time accomplish their purpose, and always make the tree fall across the river. They next cut the branches from the trunk to make it lie level. These operations are performed by the joint industry of the whole community. Some of them, at the same time, traverse the banks of the river, and cut down smaller trees, from the size of a man's leg to that of his thigh. These they cut to a certain length, dress them into stakes, and first drag them by land to the margin of the river, and then by water to the place where the building is carrying on. These piles they sink down, and interweave the branches with the larger stakes. In performing this operation, many difficulties are to be surmounted. In order to dress these stakes, and to put them in a situation nearly perpendicular, some of the beavers must elevate, with their teeth, the thick ends against the margin of the river, or against the cross tree, while others plunge to the bottom, and dig holes with their fore feet to receive the points, that they may stand on end. When some are laboring in this manner, others bring earth in their mouths and with their fore feet, and transport it in such quantities that they fill with it all the intervals between the piles. These piles consist of several rows of stakes of equal height, all placed opposite to each other, and extend from one bank of the river to the other. The stakes facing the lower part of the river are placed perpendicularly; but those which are opposed to the stream slope upward, to sustain the pressure of the water; so that the bank, which is ten or twelve feet wide at the base, is reduced to two or three at the top. Near the top, or thinnest part of the bank, the beavers make two or three sloping holes, to allow the surface water to escape. These they enlarge or contract in proportion as the river rises or falls; and, when any breaches are made in the bank by sudden or violent inundations, they know how to repair them when the water subsides.

Hitherto all these operations were performed by the united force and dexterity of the whole community. They now separate into smaller societies, which build cabins or houses. These cabins are constructed upon piles near the margin of the river or pond, and have two openings, one for the animals going to the land, and the other for throwing themselves into the water. The form of these edifices is either round or oval, and they vary in size from four or five to eight or ten feet in diameter. Some of them consist of three or four stories. Their walls are about two feet thick, and are raised perpendicularly upon planks, or plain stakes, which serve both for foundations and floors to their houses. When they consist of but one story, they rise perpendicularly a few feet only, afterwards assume a curved form, and terminate in a dome or vault, which answers the purpose of a roof. They are built with amazing solidity, and neatly plastered with a kind of stucco both within and without. These houses are impenetrable to rain, and resist the most impetuous winds. In their construction they employ different materials, as wood, stone, and a kind of sandy earth, which is not liable to be dissolved in water. The wood they use is generally of the light and tender kinds, as alders, poplars, and willows, which commonly grow on the banks of rivers, and are more easily barked, cut, and transported, than the heavier and more solid species of timber. They always begin the operation of cutting trees at a foot or a foot and a half above the ground. They labor in a sitting posture; and, beside the convenience of this posture, they enjoy the pleasure of gnawing perpetually the bark and wood, which are their favorite food. Of these provisions they lay up ample stores in their cabins to support them during the winter. Each cabin has its own magazine, which is proportioned to the number of its inhabitants, who have all a common right to the store, and never pillage their neighbors. Some villages are composed of twenty or twenty-five cabins. But these large establishments are not frequent; and the common republics seldom exceed ten or twelve families, each having its own quarter of the village, its own magazine, and its separate habitation. The smallest cabins contain two, four, or six, and the largest eighteen, twenty, and sometimes thirty beavers. As to males and females, they are almost always equally paired. Upon a moderate computation, therefore, the society is often composed of a hundred and fifty or two hundred, who all, at first, labor jointly in raising the great public building, and afterwards, in select tribes or companies, in making particular habitations.

The habitations where Moles deposit their young merit a particular description. They begin by raising the earth, and forming a pretty high arch. They leave partitions, or a kind of pillars, at certain distances, beat and press the earth, interweave it with the roots of plants, and render it so hard and solid that the water cannot penetrate the vault, on account of its convexity and firmness. They then elevate a little hillock under the principal arch; upon the latter they lay herbs and leaves for a bed to their young. In this situation they are above the level of the ground, and, of course, beyond the reach of ordinary inundations. They are, at the same time, defended from the rains by the large vault that covers the hillock, upon the convexity of which last they rest along with their young. The internal hillock is pierced on all sides with sloping holes, which descend still lower, and serve as subterraneous passages for the mother to go in quest of food for herself and her offspring. These by-paths are beaten and firm, extend about twelve or fifteen paces, and issue from the principal mansion like rays from a centre. They shut up the entrance of their retreats, and seldom leave them, unless compelled by the admission of water, or when their mansions are demolished by art.

Although the nests of Birds are not properly their habitations, but rather structures for receiving their eggs and rearing their young, some account of them comes in most appropriately in this place. They have at all times called forth the admiration of mankind. In general, they are built with an art so exquisite that an exact imitation of them exceeds all the powers of human skill and industry. Their style of architecture, the materials they employ, and the situations they select, are as various as the different species. Individuals of the same species, whatever region of the globe they inhabit, collect similar materials, arrange and construct them in the same form, and make choice of similar situations for erecting their temporary habitations; for the nests of birds, those of the eagle kind excepted, after the young have come to maturity, are usually abandoned by the parents.

There is found among the different orders a great variety both as to materials and structure. Those of the rapacious tribes are in general rude, and composed of coarse materials, as dried twigs, bents, &c. But they are often lined with soft substances. They build in elevated rocks, ruinous and sequestered castles and towers, and in other solitary retirements. The eyry or nest of the Eagle is quite flat, and not hollow, like those of other birds. The structure is so considerable, and composed of such solid materials, that it may last many years. Its form resembles that of a floor. Its basis consists of sticks about five or six feet in length, which are supported at each end, and these are covered with several layers of rushes and heath. An eagle's nest was found in the Peak of Derbyshire, which Willoughby describes in the following manner: "It was made of great sticks, resting one end on the edge of a rock, the other on a birch tree. Upon these was a layer of rushes, and over them a layer of heath, and upon the heath rushes again; upon which lay one young eagle and an addled egg, and by them a lamb, a hare, and three heathcocks. The nest was about two yards square."

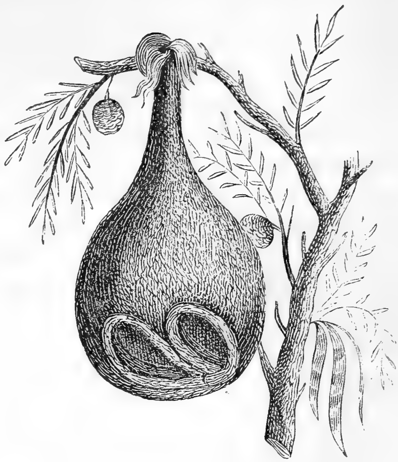
Mr. Pennant, in his "Indian Zoölogy," gives the following curious account of the manner in which the Tailor-bird builds its nest. "Had Providence," Mr. Pennant remarks, "left the feathered tribes unendowed with any particular instinct, the birds of the torrid zone would have built their nests in the same unguarded manner as those of Europe; but there, the lesser species, having a certain prescience of the dangers that surround them, and of their own weakness, suspend their nests at the extreme branches of the trees. They are conscious of inhabiting a climate replete with enemies to them and their young; with snakes that twine up the bodies of the trees, and apes that are perpetually in search of prey; but, heaven-instructed, they elude the gliding of the one, and the activity of the other. The brute creation are more at enmity with one another than in other climates; and the birds are obliged to exert an unusual artifice in placing their little broods out of the reach of an invader. Each aims at the same end, though by different means; some form their pensile nest in the shape of a purse, deep and open at top; others with a hole in the side; and others, still more cautious, with an entrance at the very bottom, forming their lodge near the summit. But the tailor-bird seems to have greater diffidence than any of the others; it will not trust its nest even to the extremity of a slender twig, but makes one more advance to safety by fixing it to the leaf itself. It picks up a dead leaf, and, surprising to relate, sews it to the side of a living one, its tender bill being its needle, and its thread some fine fibres; the lining, feathers, gossamer, and down. Its eggs are white, the color of the bird light yellow; its length three inches; its weight only three-sixteenths of an ounce; so that the materials of the nest and its own size are not likely to draw down a habitation that depends on so slight a tenure."

Fig. 50.

Nest of the Tailor-bird.

'Another instance of the same kind is found in the nest of the Baya, a small bird of India, which is built in the form of a bottle, with the entrance at its lower side. This is suspended at the end of a slender twig, so that none of its enemies can approach it. It is constructed of long grass, and has more than one apartment in its interior.'

Fig. 51.



Nest of the Baya.

Most of the cloven-footed water-fowls, or Waders, lay their eggs upon the ground. But the spoonbills and the common heron build large nests in trees, and employ twigs and other coarse materials; and the storks build on churches, or on the tops of houses. Many of the web-footed fowls lay their eggs likewise on the ground, as the terns, and some of the gulls and mergansers. But ducks pull the down from their own breasts, to afford a warmer and more comfortable bed for their young. The auks, the guillemots, and the puffins or coulternebs, lay their eggs on the naked shelves of high rocks. The penguins, for the same purpose, dig large and deep holes underground.

Fig. 52.

Nest of the Republican Grosbeak.

'The structures erected by birds are usually intended merely as places for the reception and hatching of their eggs, and they are for the most part solitary, intended for the occupation of a single pair. To this, however, there are some exceptions. A small bird called the Republican Grosbeak constructs its nest in a different manner, the same edifice containing a large number under one common roof.

'A still more remarkable example of Bird architecture is the construction of a sort of bower by the Bower-birds of Australia. These structures do not appear to be intended for hatching the eggs, but for a hall of assembly, a place of amusement to which resort is had by various individuals during the time of pairing and incubation. The following is the description given by Mr. Gould of this singular phenomenon.

"The base consists of an extensive and rather convex platform of sticks firmly interwoven, on the centre of which the bower itself is built; this, like the platform on which it is placed, and with which it is interwoven, is formed of sticks and twigs, but of a more slender and flexible description, the tips of the twigs being so arranged as to curve inward and nearly meet at the top. In the interior of the bower, the materials are so placed that the forks of the twigs are always presented outwards, by which arrangement not the slightest obstruction is offered to the passage of the birds. The interest of this curious bower is much enhanced by the manner in which it is decorated at and near its entrance with the most gayly colored articles that can be collected, such as the blue tail-feathers of the rose-bill and Pennantian parrots, bleached bones, the shells of snails, &c. Some of the feathers are stuck in among the twigs, while others, with the bones and shells, are strewed about near the entrances. The propensity of these birds to pick up, and fly off with, any attractive object is so well known to the natives that they always search the *runs*, as these structures are called, for any small missing article that may have been accidentally dropped in the brush. I myself found at the entrance of one of them a small, neatly-worked stone tomahawk, of an inch and a half in length, together with some slips of blue cotton rags, which the birds had doubtless picked up at a deserted encampment of the natives."

'One of the most curious of the structures reared by birds for the reception of their eggs is that of the Brush Turkey of Australia, a species nearly as large as the common species. Instead of hatching out their young by the heat of their own bodies, they collect a quantity of vegetable matter into a large heap, by the decay of which sufficient heat is evolved for the purpose. They construct in fact a kind of hotbed. Several weeks are employed in bringing the materials together, till at length a mound, consisting of from two to four cart-loads, is formed. This is not the work of a single pair; many join in the work. When the labor is completed, the eggs are buried two or three feet deep in the fermenting mass, and in due time the young bird is hatched, and extricates itself, the parents taking no further interest in their offspring. There are other birds that deposit their eggs in mounds, sometimes of mere sand; and it is worthy of remark that even the males, when in confinement, from the mere suggestion of blind instinct, occupy themselves in preparing similar mounds!

'The largest nests of birds ever noticed are those found on the coast of Australia by Captains Cook and Flinders. They were built of sticks and branches of trees upon the ground, and were no less than twenty-six feet in circumference and thirty-two inches high, the materials of which each was composed being enough to fill a cart. No known living bird is large enough to have built, or to occupy, such a nest. It has been conjectured that it might have belonged to the gigantic species whose bones have been found in New Zealand, and that the fossil footmarks found upon sandstone on the Connecticut belonged to animals of a similar gigantic size.'

'The most remarkable examples of animal architecture are found among the habitations of Insects. Some of these are constructed by single individuals, and others are the result of the combined labors of large associations. The main purpose in all seems to be to provide a secure retreat in which to deposit their eggs and rear their young. Its use as a habitation is secondary and incidental. The nests of the Mason Bee are composed of a kind of mortar, whence its name, and are affixed to the sides of houses or other walls, and have the appearance of accidental prominences of dirt or clay. The interior consists of an assemblage of different cells, each of which affords shelter to one of the young. The mortar of which these cells are built, is composed of sand mixed with, and made coherent by, a glutinous secretion from the body of the female parent, who is alone occupied in this labor. In each of these cells an egg is hatched into a small, white worm; and, the vacant space having been filled up by the indefatigable parent with a paste composed of farina and honey, upon this the young animal feeds until it has accomplished its metamorphoses. It then makes its way through the covering of the cell, and takes flight into the open air.

'The nests of another species of solitary bee are built in the substance of the wood of soft or decaying trees. They consist of a long canal dug out by the teeth of the insect, which is then divided by a succession of partitions into a number of cells, one above another, in each of which an egg is laid, and surrounded by a similar deposit of food for the future young. But the wise precautions thus taken by the careful mother are often defeated by a cunning enemy. Before the cells are finally closed, the ichneumon-fly deposits in them its own eggs, and the larvæ proceeding from them devour not only the provisions laid up by the bee, but also her progeny whom she has labored so hard to protect.'

Another small species of solitary bee dig holes in the earth to make a convenient habitation for their young. Their nests are composed of cylindrical cells, fixed to one another, and each of them, in figure, resembling a thimble. Their bottom, of course, is convex or rounded. The bottom of the second is inserted into the entry of the first; and the entry of the second receives the bottom of the third. They are not all of the same length. Some of them are five lines long, others only four, and their diameters seldom exceed two lines. Sometimes only two of these cells are joined together; and, at other times, we find three or four, which form a kind of cylinder. This cylinder is composed of alternate bands of two different colors; the narrowest, at the juncture of two cells, are white, and the broadest are of a reddish brown. The cells consist of a number of fine membranes, formed of a glutinous and transparent substance from the animal's mouth. Each cell our bee fills with the farina of flowers diluted with honey, and in this paste she deposits an egg. She then covers the cell, by gluing to its mouth a fine cellular substance taken from the leaves of some plant; and in this manner she proceeds till her cylindrical nest is completed. The worms which are hatched from the eggs feed upon the paste, so carefully laid up for them by the mother, till they are transformed into flies similar to their parents.

Some examples of the operations of associating insects, who construct habitations by exerting a common and mutual labor, may next be noticed.

In the formation of their combs, Bees seem to resolve a problem which would be not a little puzzling to some geometers, namely, a quantity of wax being given, to make of it equal and similar cells, of a determined capacity, but of the largest size in proportion to the quantity of matter employed, and disposed in such a manner as to occupy in the hive the least possible space. Every part of this problem is completely executed by the bees. By applying hexagonal cells to each other's sides, no void spaces are left between them; and, though the same end might be accomplished by other figures, yet they would necessarily require a greater quantity of wax. Besides, hexagonal cells are better fitted to receive the cylindrical bodies of these insects. A comb consists of two strata of cells applied to each other's ends. This arrangement both saves room in the hive, and it gives a double entry into the cells of which the comb is composed. As a further saving of wax, and preventing void spaces, the bases of these cells in one stratum of a comb serve for bases to the opposite stratum. In a word, the more minutely the construction of these cells is examined, the more will the admiration of the observer be excited. The walls of the cells are so extremely thin that their mouths would be in danger of suffering by the entering and issuing of the bees. To prevent this disaster, they make a kind of ring round the margin of each cell, and this ring is three or four times as thick as the walls.

The cells of bees are designed for different purposes. Some of them are employed for the accumulation and preservation of honey. In others the female deposits her eggs, and from these eggs worms are hatched, which remain in the cells till their final transformation into flies. The drones, or males, are larger than the common, or working bees; and the queen, or mother of the hive, is much larger than either. A cell destined for the lodgment of a male or female worm, must, therefore, be considerably larger than the cells of the smaller working bees. The number of cells destined for the reception of the working bees far exceeds that of the cells in which the males are lodged. The honey cells are always made deeper and more capacious than the others. When the honey collected is so abundant that the vessels cannot contain it, the bees lengthen, and, of course, deepen, the honey cells.

Their mode of working, and the disposition and division of their labor, when put into an empty hive, do much honor to the sagacity of bees. They immediately begin to lay the foundations of their combs, which they execute with surprising quickness and alacrity. Soon after they begin to construct one comb, they divide into two or three companies, each of which, in different parts of the hive, is occupied with the same operations. By this division of labor, a greater number of bees have an opportunity of being employed at the same time, and, consequently, the common work is sooner finished. The combs are generally arranged in a direction parallel to each other. An interval, or street, between the combs, is always left, that the bees may have a free passage, and an easy communication with the different combs in the hive. These streets are just wide enough to allow two bees to pass one another. Beside these parallel streets, to shorten their journey when working they leave several round cross passages, which are always covered.

Bees carry into their hives, by means of their hind thighs, great quantities of the farina, or dust, of flowers. After many experiments made by Réaumur, with a view to discover whether this dust contained real wax, he was obliged to acknowledge that he could never find that wax formed any part of its composition. He at length discovered, that wax was not a substance produced by the mixture of farina with any glutinous substance, nor by trituration, or any mechanical operation. By long and attentive observation, he found that the bees actually eat the farina which they so industriously collect; and that this farina, by an animal process, is converted into wax. This digestive process, which is necessary to the formation of wax, is carried on in the second stomach, and perhaps in the intestines, of bees. After knowing the place where this operation is performed, chemists will probably allow that it is equally difficult to make real wax with the farina of flowers, as to make chyle with animal or vegetable substance, a work which is daily executed by our own stomach and intestines, and by those of other animals. Réaumur likewise discovered that all the cells in a hive were not destined for the reception of honey and for depositing the eggs of the female, but that some of them were employed as receptacles for the farina of flowers, a species of food that bees find necessary for the formation of wax, which is the great basis and raw material of all their curious operations.* As a further evidence that the bees actually eat the farina of flowers, when the stomach and intestines are laid open, they are often found to be filled with this dust, the grains of which, when examined by the microscope, have the exact figure, color, and consistence of farina, taken from the anthers of particular flowers.

After the farina is digested, and converted into wax, the bees possess the power of bringing it from their stomachs to their mouths. The instrument they employ in furnishing materials for constructing their waxen cells is their tongue. This tongue is situated below the two teeth or fangs. When at work, the tongue may be seen by the assistance of a lens and a glass hive. It is then in perpetual motion, and its motions are extremely rapid. Its figure continually varies. Sometimes it is more sharp; at others it is flatter; and sometimes it is more or less concave, and

* 'Few observers in Natural History are more worthy of entire confidence than Réaumur, whose account of the food of bees and the formation of wax is given by Mr. Smellie in the text. Still, the accuracy of his observations has been called in question by subsequent writers, especially by Huber. According to him, there are two kinds of neuters, — *nurse-bees* and *wax-makers*. The nurse-bees feed and take care of the young grubs, and perform some other offices in the hive. The wax-workers are rather larger than the nurse-bees. Wax is secreted from honey, and, when wax is wanted in the hive, the wax-makers gorge themselves with it, and then remain in a state of entire rest for several hours, sometimes for twenty-four, till the wax appears in scales between the rings of the abdomen. Farina is swallowed by the nurse-bees, and then formed into a kind of paste, with which they feed the grubs.

'The food of bees is always honey, the sweet juice of fruits, or some other kind of saccharine matter. The workers feed the nurse-bees, and they also lay up a store of honey for future use. Farina is also laid up in the same way.'

partly covered with a moist paste or wax. By the different movements of its tongue, the bee continues to supply fresh wax to the two teeth, which are employed in raising and fashioning the walls of its cell, till they have acquired a sufficient height. As soon as the moist paste or wax dries, which it does almost instantaneously, it then assumes all the appearances and qualities of common wax. There is a still stronger proof that wax is the result of an animal process. When bees are removed into a new hive, and closely confined from the morning to the evening, if the hive chances to please them, in the course of this day several waxen cells will be formed, without the possibility of a single bee's having had access to the fields. Besides, the rude materials, or the farina of plants carried into the hive, are of various colors. The farina of some plants employed by the bees is whitish; in others, it is of a fine yellow color; in others, it is almost entirely red; and in others, it is green. The combs constructed with these differently colored materials are, however, uniformly of the same color. Every comb, especially when it is newly made, is of a pure white color, which is more or less tarnished by age, by the operation of the air, or by other accidental circumstances. To bleach wax, therefore, requires only the art of extracting such foreign bodies as may have insinuated themselves into its substance, and changed its original color.

Bees, from the nature of their constitution, require a warm habitation. They are likewise extremely solicitous to prevent insects of any kind from getting admittance into their hives. To accomplish both these purposes, when they take possession of a new hive, they carefully examine every part of it; and, if they discover any small holes or chinks, they immediately paste them firmly up with a resinous substance, which differs considerably from wax. This substance was not unknown to the ancients. Pliny mentions it under the name of *propolis*, or bee-glue. Bees use the propolis for rendering their hives more close and perfect, in preference to wax, because the former is more durable, and more powerfully resists the vicissitudes of weather, than the latter. This glue is not, like wax, procured by an animal process. The bees collect it from different trees, as the poplars, the birches, and the willows. After a bee has procured a quantity sufficient to fill the cavities in its two hind thighs, it repairs to the hive. Two of its companions instantly draw out the propolis, and apply it to fill up such chinks, holes, or other deficiencies, as they find in their habitation. But this is not the only use to which bees apply the propolis. They are extremely solicitous to remove such insects or foreign bodies as happen to get admission into the hive. When so light as not to exceed their powers, they first kill the insect with their stings, and then drag it out with their teeth. But it sometimes happens that an ill-fated snail creeps into the hive. It is no sooner perceived, than it is attacked on all sides, and stung to death. But how are the bees to carry out a burden of such weight? This labor they know would be in vain. They are, perhaps, apprehensive that a body so large would diffuse, in the course of its putrefaction, a disagreeable or noxious odor through the hive. To prevent such hurtful consequences, immediately after the animal's death they embalm it by covering every part of its body with propolis, through which no effluvia can escape. When a snail with a shell gets entrance, to dispose of it gives much less trouble and expense to the bees. As soon as this kind of snail receives the first wound from a sting, it naturally retires within its shell. In this case, the bees, instead of pasting it all over with propolis, content themselves with gluing all round the margin of the shell, which is sufficient to render the animal for ever immovably fixed.

But propolis and the materials for making wax are not the only substances these industrious animals have to collect. As formerly remarked, beside the whole winter there are many days in which the bees are prevented by the weather from going abroad in quest of provisions. They are, therefore, under the necessity of collecting, and laying up in cells destined for that purpose, large quantities of honey. This sweet and balsamic liquor they extract, by means of their proboscis or trunk, from the nectariferous glands of flowers. The trunk of a bee is a kind of rough cartilaginous tongue. After collecting a small quantity of honey, the animal with its proboscis conveys it to its mouth, and swallows it. From the œsophagus, or gullet, it passes into the first stomach, which is more or less swelled in proportion to the quantity of honey it contains. When empty, it has the appearance of a fine, white thread; but, when filled with honey, it assumes the figure of an oblong bladder, the membrane of which is so thin and transparent that it allows the color of the liquor it contains to be distinctly seen. This bladder is well known to children who live in the country. They cruelly amuse themselves with catching bees, and tearing them asunder, in order to suck the honey. A single flower furnishes but a small quantity of honey. The bees are therefore obliged to fly from one flower to another till they fill their first stomachs. When they have accomplished this purpose, they return directly to the hive, and disgorge in a cell the whole of the honey they have collected. It not unfrequently happens, however, that, when on its way to the hive, it is accosted by a hungry companion. How the one can communicate its necessity to the other, it is perhaps impossible to discover. But the fact is certain, that, when two bees meet in this situation, they mutually stop, and the one whose stomach is full of honey extends its trunk, opens its mouth, which lies a little beyond the teeth, and, like ruminating animals, forces up the honey into that cavity. The hungry bee knows how to take advantage of this hospitable invitation. With the point of its trunk it sucks the honey from the other's mouth. When not stopped on the road, the bee proceeds to the hive, and in the same manner offers its honey to those who are at work, as if it meant to prevent the necessity of quitting their labor in order to go in quest of food. In bad weather, the bees feed upon the honey laid up in open cells; but they never touch these reservoirs when their companions are enabled to supply them with fresh honey from the fields. But the mouths of those cells which are destined for preserving honey during winter, they always cover with a lid or thin plate of wax.

Wasps, like bees, associate in great numbers, and construct, with much dexterity and skill, a common habitation. Their architecture, like that of the honey-bee, is singular and worthy of admiration; but the materials employed furnish neither honey nor wax. Impelled by an instinctive love of posterity, they, with great labor, skill, and assiduity, construct combs, which are likewise composed of hexagonal or six-sided cells. Though these cells are not made of wax, they are equally proper for the reception of eggs, and for affording convenient habitations to the worms which proceed from them, till their transformation into wasps.

In general, the cells of the wasps are formed of a kind of paper, which, with great dexterity, is fabricated by the animals themselves. The number of combs and cells in a wasps' nest is always proportioned to the number of individuals associated. Different species choose different situations for building their nests. Some expose their habitations to all the injuries of the air; others prefer the trunks of decayed trees; and others, as the common kind, of which we are principally treating, conceal their nests under ground. The hole which leads to a wasps' nest is about an inch in diameter. This hole is a kind of gallery mined by the wasps, is seldom in a straight line, and varies in length from half a foot to two feet, according to the distance of the nest from the surface of the ground. When exposed to view, the whole nest appears to be of a roundish form, and sometimes about twelve or fourteen inches in diameter. It is strongly fortified all round with walls or layers of paper, the surface of which is rough and irregular. In these walls, or rather in this external covering, two holes are left for passages to the combs. The wasps uniformly enter the nest by one hole, and go out by the other, which prevents any confusion or interruption to their common labors.

Upon removing the external covering, we perceive that the whole interior part consists of several stories or floors of combs, which are parallel to each other, and nearly in a horizontal position. Every story is composed of a numerous assemblage of hexagonal cells, very regularly constructed with a matter resembling ash-colored paper. These cells contain neither wax nor honey, but are solely destined for containing the eggs, the worms which are hatched from them, the nymphs, and the young wasps till they are able to fly. Wasps' nests are not always composed of an equal number of combs. They sometimes consist of fifteen, and sometimes of eleven only. The combs are of various diameters. The first, or uppermost, is often only two inches in diameter, while those of the middle sometimes exceed a foot. The lowest are also much smaller than the middle ones.

All these combs, like so many floors or stories ranged in a parallel manner above each other, afford lodging to prodigious numbers of inhabitants. Réaumur computed, from the number of cells in a given portion of comb, that, in a medium-sized nest, there were at least ten thousand cells. This calculation gives an idea of the astonishingly prolific powers of these insects, and the vast numbers of individuals produced in a single season from one nest; for every cell serves as a lodging to no less than three generations. Hence a moderately-sized nest gives birth annually to thirty thousand young wasps.

The different stories of combs are always about half an inch high, which leaves free passages to the wasps from one part of the nest to another. These intervals are so spacious, that, in proportion to the bulk of the animals, they may be compared to great halls or broad streets. Each of the larger combs is supported by about fifty pillars, which, at the same time, give solidity to the fabric, and greatly ornament the whole nest. The lesser combs are supported by the same ingenious contrivance. These pillars are coarse, and of a roundish form. Their bases and capitals, however, are much larger in diameter than the middle. By the one end they are attached to the superior comb, and by the other to the inferior. Thus between two combs there is always a species of rustic colonnade. The wasps begin at the top, and build downward. The uppermost and smallest comb is first constructed. It is attached to the superior part of the external covering. The second comb is fixed to the bottom of the first; and in this manner the animals proceed till the whole operation is completed. The connecting pillars are composed of the same kind of paper as the rest of the nest. To allow the wasp entries into the void spaces, roads are left between the combs and the external envelope or covering.

A general idea of this curious edifice having been given, it is next natural to inquire how the wasps build, and how they employ themselves in their abodes. But as all these mysteries are performed under cover, it required much industry and attention to discover them. By the ingenuity and perseverance of M. de Réaumur, however, we are enabled to explain some parts of their internal economy and manners. This indefatigable naturalist contrived to make wasps, like the honey-bees, lodge and work in glass hives. In this operation he was greatly assisted by the ardent affection which these animals have to their offspring; for he found, that, though the nest was cut in different directions, and though it was exposed to the light, the wasps never deserted it, nor relaxed in their attention to their young.

Immediately after a wasp's nest has been transported from its natural situation, and covered with a glass hive, the first operation of the insects is to repair the injuries it has suffered. With wonderful activity they carry off all the earth and foreign bodies that may have accidentally been conveyed into the hive. Some of them occupy themselves in fixing the nest to the top and sides of the hive by pillars of paper, similar to those which support the different stories or strata of combs; others repair the breaches it has sustained; and others fortify it by augmenting considerably the thickness of its external cover. This external envelope is an operation peculiar to wasps. Its construction requires great labor; for it frequently exceeds an inch and a half in thickness, and is composed of a number of strata or layers as thin as paper, between each of which there is a void space. This cover is a kind of box for inclosing the combs, and defending them from the rain which might otherwise penetrate them. For this purpose it is admirably adapted. If it were one solid mass, the contact of water would penetrate the whole and reach the combs. But to prevent this fatal effect, the animals leave considerable vacuities between the vaulted layers, which are generally fifteen or sixteen in number. By this ingenious piece of architecture, one or two layers may be moistened with water, while the others are not in the least affected.

The materials employed by wasps in the construction of their nests are very different from those made use of by the honey-bee. Instead of collecting the farina of flowers, and digesting it into wax, the wasps gnaw with their two fangs, which are strong and serrated, small fibres of wood from the sashes of windows, the posts of espaliers, garden doors, &c., but never attempt growing or green timber. These fibres, though very slender, are often a line, or a twelfth part of an inch long. After cutting a certain number of them, the animals collect them into minute bundles, transport them to their nest, and, by means of a glutinous substance furnished from their own bodies, form them into a moist and ductile paste. Of this substance, or *papier maché*, they construct the external cover, the partitions of the nest, the hexagonal cells, and the solid columns which support the several layers or stories of combs.

The constructing of the nest occupies a comparatively small number of laborers. The others are differently employed. Here it is necessary to remark, that the republics of wasps, like those of the honey-bees, consist of three kinds of flies, males, females, and neuters. Like the bees, also, the number of neuters far surpasses that of both males and females. The greatest quantity of labor is devolved upon the neuters; but they are not, like the neuter bees, the only workers; for there is no part of their operations which the females, at certain times, do not execute. Neither do the males, though their industry is not comparable to that of the neuters, remain entirely idle. They often occupy themselves in the interior part of the nest. The greatest part of the labor, however, is performed by the neuters. They build the nest, feed the males, the females, and even the young. But while some of the neuters are employed in these different operations, the others are abroad in hunting parties. Some attack with intrepidity live insects, which they sometimes carry entire to the nest; but they generally transport the abdomen or belly only. Others pillage butchers' stalls, from which they often arrive with a piece of meat larger than the half of their own bodies. Others resort to gardens, and suck the juices of fruits. When they return to the nest, they distribute a part of their plunder to the females, to the males, and even to such neuters as have been usefully occupied at home. As soon as a neuter enters the nest, it is surrounded by several wasps, to each of whom it freely gives a portion of the food it has brought. Those who have not been hunting for prey, but have been sucking the juices of fruits, though they seem to return empty, fail not to regale their companions; for, after their arrival, they station themselves upon the upper part of the nest, and discharge from their mouths two or three drops of a clear liquid, which are immediately swallowed by the domestics.

The neuter wasps, though the most laborious, are the smallest; but they are extremely active and vivacious. The females are much larger, heavier, and slower in their movements. The males are of an intermediate size between that of the females and that of the neuters. From these differences in size, it is easy to distinguish the different kinds of those wasps which build their nests below the ground. In the hive of the honey-bee, the number of females is always extremely small; but in a wasps' nest there are often more than three hundred females. During the months of June, July, and August, they remain constantly in the nest, and are never seen abroad except in the beginning of spring, and in the months of September and October. During the summer, they are totally occupied in laying their eggs and feeding their young. In this last operation, they are assisted by the other wasps; for the females alone, though numerous, would be insufficient for the laborious task. The eggs are white, transparent, of an oblong figure, and differ in size according to the kind of wasps which are to proceed from them. Some of them are no larger than the head of a small pin. They are so firmly glued to the bottoms of the cells, that it is with difficulty they can be detached without breaking. Eight days after the eggs are deposited in the cells, the worms are hatched, and are considerably larger than the eggs which gave birth to them. These worms demand the principal cares of the wasps who continue always in the nest. They feed them, as birds feed their young, by giving them, from time to time, a mouthful of food. It is astonishing to see with what industry and rapidity a female runs along the cells of a comb, and distributes to each worm a portion of nutriment. In proportion to the ages and conditions of the worms, they are fed with solid food, such as the bellies of insects, or with a liquid substance disgorged by the mother. When a worm is so large as to occupy its whole cell, it is then ready to be metamorphosed into a nymph. It then refuses all nourishment, and ceases to have any connection with the wasps in the nest. It shuts up the mouth of its cell with a fine silken cover, in the same manner as the silkworm and other caterpillars spin their cods. This operation is completed in three or four hours, and the animal remains in the nymph state nine or ten days, when, with its teeth, it destroys the external cover of the cell, and comes forth in the form of a winged insect. In a short time, the wasps newly transformed receive the food brought into the nest by the foragers in the fields. What is still more curious, in the course of the first day after their transformation, the young wasps have been observed going to the fields, bringing in provisions, and distributing them to the worms in the cells. A cell is no sooner abandoned by a young wasp, than it is cleaned, trimmed, and repaired by an old one, and rendered, in every respect, proper for the reception of another egg.

This wonderful assemblage of combs, of the pillars which support them, and of the external envelope, is an edifice which requires several months' labor, and serves the animals one year only. This habitation, so populous in summer, is almost deserted in winter, and abandoned entirely in spring; for, in this last season, not a single wasp is to be found in a nest of the preceding year. It is worthy of remark, that the first combs of a nest are always accommodated for the reception of the neuter, or working, wasps. The city, of which the foundation has just been laid, requires a number of workmen. The neuter, or working, wasps are accordingly first produced. A cell is no sooner half completed, than an egg of a neuter is deposited in it by the female. Of fourteen or fifteen combs inclosed in a common cover, the last four only are destined for the reception of males and females. Hence it uniformly happens, that, before the males and females are capable of taking flight, every wasp's nest is peopled with several thousand neuters, or workers. But the neuters, who are first produced, are likewise the first that perish; for not one of them survives the termination even of a mild winter.

The female wasps are stronger, and support the rigors of winter better than the males or neuters. Before the end of winter, however, several hundred females die, and not above ten or a dozen in each nest survive that season. These few females are destined for the continuation of the species. Each of them becomes the founder of a new republic. When a queen bee departs from a hive, in order to establish a new one, she is always accompanied with several thousand industrious laborers, ready to perform every necessary operation. But the female wasp has not the aid of a single laborer; for all the neuters are dead before the beginning of the spring. The female alone lays the foundation of a new republic. She either finds or digs a hole under the earth, builds cells for the reception of her eggs, and feeds the worms which proceed from them. Whenever any of these neuter worms are transformed into flies, they immediately assist their parent in augmenting the number of cells and combs, and in feeding the young worms which are daily hatching from the eggs. In a word, this female wasp, which in spring was perfectly solitary, without any proper habitation, and had every operation to perform, has, in autumn, several thousands of her offspring at her devotion, and is furnished with a magnificent palace, or rather city, to protect her from the injuries of the weather and from external enemies.

With regard to the male wasps, it is uncertain whether any of them survive the winter. But, though not so indolent as the males of the honey-bee, they can be of little assistance to the female; for they never engage in any work of importance, such as constructing cells, or fortifying the external cover of the nest. They are never brought forth till towards the end of August; and their sole occupation seems to be that of keeping the nest clean. They carry out every kind of filth, and the carcasses of such of their companions as happen to die. In performing this operation, two of them often join; and, when the load is too heavy, they cut off the head, and transport the dead animal at two different times.

The males and females are produced at the same time, and they are nearly equal in number. Like the male honey-bees, the male wasps are destitute of stings; but the females and neuters have stings, the poisonous liquor of which, when introduced into any part of the human body, excites inflammation, and creates a considerable degree of pain.

'The habitations and economy of the various species of Ants are equally curious with those which have been described. There are, as with the wasps and bees, individuals of three sorts; males and females, which have wings, and neuters, which are without them. The former desert the habitations in which they have been reared, as soon as they have undergone the last metamorphosis, and seldom revisit them. They live principally in the air, like other insects, forming numerous swarms. The females, as soon as they are ready to deposit their eggs, wander from their place of birth, deprive themselves of their wings by means of their feet, and found a new establishment, whilst the males, having become entirely useless, all perish. A few of the females are seized by the neuters, confined in the original habitation, deprived of their wings, and obliged to lay their eggs there, and are then driven out to perish.

'The neuters are distinguished not only by the want of wings, but by the size of their head, the strength of their jaws, and the length of their feet. They have charge of the principal part of the labor of preparing for the reception and nourishment of the young. The nests of ants differ very much in different species. They are generally made in the earth. Some merely dig out the sand and form holes running in different directions, so that the habitation is almost entirely subterraneous. Others gather together particles of many different kinds, and raise mounds of considerable size above the surface of the earth in the form of domes. Others choose for their residence the trunks of old trees, the interior of which they pierce with holes passing in every direction. All the passages or galleries of which these habitations consist, terminate in an apartment designed for the reception of the young.

'The food of ants consists of fruit, insects and their larvæ, and the bodies of small quadrupeds and birds. The neuters, which are the providers for the whole establishment, are principally governed in their researches by the senses of touch and smell. With the fruits of their labors they feed the larvæ while in a helpless state. In warm weather they drag them up for the benefit of the heat to the outside of their holes, and, at the approach of night or of bad weather, convey them back again into the recesses of their habitations. In short, all their labor and care are directed with a view to the accommodation and preservation of an offspring in which they really have no share. They defend them against the attack of all enemies, and risk for them their safety and their lives; and, after watching them with unremitting assiduity until they have arrived at the perfect state, they will not then suffer them to leave the nest unless the weather be fine and propitious, when they permit them to take their departure.

'The male and female ants perish at the approach of winter, but the neuters survive it, and pass the cold months in a dormant state in the recesses of their habitations. Their forethought and providence, then, in the provision of food, has not for its object their own support, but that of the young; and, in preparing for the winter, they have merely to render their habitations tight and secure against the cold.'

The habitations and operations of the Termites, a species of insects frequently called white ants, although of a different genus, and even a different order, from the common ants, are well worthy of attention. They infest Guinea, and all the tropical regions, where, for their depredations upon property, they are greatly dreaded by the inhabitants.

Of these insects there are several species; but they all resemble each other in form, and in their manner of living. They differ, however, as much as birds, in the style of their architecture, and in the selection of the materials of which their nests are composed. Some build on the surface, or partly above and partly below the ground, and others on the trunks or branches of lofty trees.

Before describing the nests or hills, it is necessary to give some idea of the animals themselves, and of their general economy and manners. We shall confine ourselves to that species called *termites bellicosi*, or fighters, because they are the largest and best known.

The republic of the *termites bellicosi*, like those of the other species of this genus, consists of three ranks or orders of insects; 1. The working insects, which have been distinguished by the name of *laborers;* 2. The fighters or *soldiers*, which perform no kind of labor; and, 3. The winged or perfect insects, which are male and female. These last have been called the *nobility* or *gentry*, because they neither labor nor fight. The nobility alone are capable of being raised to the rank of kings and queens. A few weeks after their elevation to this state, they emigrate, in order to establish new empires.

In a nest or hill, the laborers, or working insects, are always most numerous. There are at least one hundred laborers to one of the fighting insects or soldiers. When in this state, they are about a fourth of an inch in length, which is rather smaller than some of our ants. From their figure and fondness for wood, they are very generally known by the name of *wood-lice.*

The second order, or soldiers, differ in figure from that of the laborers. The former have been supposed to be neuters, and the latter males. But, in fact, they are the same insects. They have only undergone a change of form, and made a nearer approach to the perfect state. They are now much larger, being half an inch in length, and equal in size to fifteen of the laborers. The form of the head is likewise greatly changed. In the laborer state, the mouth is evidently formed for gnawing or holding bodies; but in the soldier state, the jaws, being shaped like two sharp awls a little jagged, are destined solely for piercing or wounding. For these purposes they are very well calculated; for they are as hard as a crab's claw, and placed in a strong, horny head, which is of a nutbrown color, and larger than the whole body.

The figure of the third order, or that of the insect in its perfect state, is still more changed. The head, the thorax, and the abdomen, differ almost entirely from the same parts in the laborers and the soldiers. Beside, the animals are now furnished with four large, brownish, transparent wings, by which they are enabled, at the proper season, to emigrate and to establish new settlements. In the winged or perfect state they are greatly altered in their size as well as in their figure. Their bodies now measure between six and seven tenths of an inch, their wings, from tip to tip, above two inches and a half, and their bulk is equal to that of thirty laborers, or two soldiers. Instead of active, industrious, and rapacious little animals, when they arrive at their perfect state, they become innocent, helpless, and dastardly. Their numbers are great; but their enemies are still more numerous. They are devoured by birds, by every species of ants, by carnivorous reptiles, and even by the inhabitants of many parts of Africa.

Of those that escape, some are seized upon by the laboring insects, and are made the founders of new states. They are immediately inclosed in a chamber suitable to their size. This is built around them, and has an entrance too small for them to go out, but large enough for the laborers to pass in and out. It was the opinion of former observers, that both males and females were thus preserved; but the analogy of other insects renders it probable that it is females alone. At any rate, there soon takes place a most extraordinary change in the female or queen. Her abdomen is gradually extended and enlarged to a most enormous size; so that in an old queen it has been found to have increased to one thousand five hundred or two thousand times the bulk of the rest of the body, and twenty or thirty thousand times the bulk of a common laborer. The skin extends in every direction, so that the abdomen, which is not originally more than half an inch in length, has at last each of its segments removed to that distance from each other. When the animal is two years old, the abdomen has increased to three inches in length, and it has sometimes been found of twice that size. This is now full of eggs, contained in a vast number of very minute and convoluted vessels, which, moving in a serpentine manner, cause an undulating appearance without, like that of the peristaltic motion of the intestines. By means of this motion, the eggs are protruded in almost incredible numbers, to the amount, as has been pretty accurately calculated, of eighty thousand or upward in twenty-four hours.

The eggs are instantly taken care of by the laborers, and placed in proper depositories or nurseries, where they are hatched. The young are then attended, and provided with every thing necessary until they are able to shift for themselves, and take their share in the labors of the community.

The nests of the termites bellicosi, or wood-lice, are called hills by the natives of Africa, Australia, and other hot climates. This appellation is highly proper; for they are often elevated ten or twelve feet above the surface of the earth, and are nearly of a conical figure. These hills, instead of being rare phenomena, are so frequent in many places near Senegal, that, as described with great propriety by M. Adanson, their number, magnitude, and closeness of situation, make them appear like villages of the negroes. "Of all the extraordinary things I observed," says M. Adanson, in his voyage to Senegal, "nothing struck me more than certain eminences, which, by their height and regularity, made me take them, at a distance, for an assemblage of negro huts, or a considerable village, and yet they were only the nests of certain insects. These nests are round pyramids, from eight to ten feet high, upon nearly the same base, with a smooth surface of rich clay, excessively hard and well built."

Each of these hills is composed of an exterior and an interior part. The exterior cover is a large clay shell, which is shaped like a dome. Its strength and magnitude are sufficient to inclose and protect the interior building from the injuries of the weather, and to defend its numerous inhabitants from the attacks of natural or accidental enemies. The external dome or cover is, therefore, always much stronger than the internal building, which is the habitation of the insects, and is divided with wonderful artifice and regularity into a vast number of apartments for the residence and accommodation of the king and queen, for the nursing of their progeny, and for magazines, which are always well stored with provisions.

These hills make their first appearance in the form of conical turrets, about a foot high. In a short time, the insects erect, at a little distance, other turrets, and go on increasing their number and widening their basis till their under works are covered with these turrets, which the animals always raise highest in the middle of the hill, and, by filling up the intervals between them, collect them at last into one great dome.

The royal chamber appears to be, in the opinion of this little people, of the most consequence, and is always situated as near the centre of the interior building as possible, and generally about the height of the common surface of the ground. It is always nearly in the shape of half an egg, or an obtuse oval, within, and may be supposed to represent a long oven. In the infant state of the colony, it is not above an inch, or thereabouts, in length; but, in time, will be increased to six or eight inches, or more, in the clear, being always in proportion to the size of the queen, who, increasing in bulk as in age, at length requires a chamber of such dimensions.

The royal chamber is surrounded by an innumerable quantity of others, which are of different sizes, figures, and dimensions; but all of them are arched in either a circular or an elliptical form. These chambers enter into each other, or have communicating passages, which, being always clear, are evidently intended for the conveniency of the soldiers and attendants, of whom, as will soon appear, great numbers are necessary. These apartments are joined by the magazines and nurseries. The magazines are chambers of clay, and are at all times well stored with provisions, which, to the naked eye, seem to consist of the raspings of wood and plants which the termites destroy; but, when examined by the microscope, they are found to consist chiefly of the gums or inspissated juices of plants, thrown together in small irregular masses.

The magazines are always intermixed with the nurseries, which last are buildings totally different from the rest of the apartments. They are composed entirely of wooden materials, which seem to be cemented with gums. They are invariably occupied by the eggs, and the young ones, which first appear in the shape of laborers; but then they are as white as snow. These buildings are exceedingly compact, and are divided into a number of small, irregularly-shaped chambers, not one of which is half an inch wide.

When a nest or hillock is in the infant state, the nurseries are close to the royal apartment. But as, in process of time, the body of the queen enlarges, it becomes necessary, for her accommodation, to augment the dimensions of her chamber. She then, likewise, lays a greater number of eggs, and requires more attendants; of course, it is necessary that both the number and dimensions of the adjacent apartments should be augmented. For this purpose, the small, first-built nurseries are taken to pieces, rebuilt a little farther off, and made a size larger; and their number, at the same time, is increased. Thus the animals are continually employed in pulling down, repairing, or rebuilding their apartments; and these operations they perform with wonderful sagacity, regularity, and foresight.

The royal chamber is situated nearly on a level with the surface of the ground, at an equal distance from all the sides of the building, and directly under the apex of the hill. On all sides, both above and below, it is surrounded by what are called the royal apartments, which contain only laborers and soldiers, who can be intended for no other purpose than to continue in the nest either to guard or serve their common parents, on whose safety the happiness, and, in the estimation of the negroes, the existence of the whole community depends. These apartments compose an intricate labyrinth, which extends a foot or more in diameter from the royal chamber on every side. Here the nurseries and magazines of provisions begin; and, being separated by small empty chambers and galleries, which surround them, and communicate with each other, are continued on all sides to the outward shell, and reach up within it two thirds or three fourths of its height, leaving an open area in the middle under the dome, which resembles the nave of an old cathedral. This area is surrounded by large Gothic arches, which are sometimes two or three feet high next the front of the area, but diminish rapidly as they recede, like the arches of aisles in perspective, and are soon lost among the inumerable chambers and nurseries behind them. All these chambers and passages are arched, and contribute mutually to support one another. The interior building, or assemblage of nurseries, chambers, and passages, has a flattish roof, without any perforation. By this contrivance, if by accident water should penetrate the external dome, the apartments below are preserved from injury. The area has also a flattish floor, which is situated above the royal chamber. It is likewise water-proof, and so constructed, that if water gets admittance it runs off by subterraneous passages, which are of an astonishing magnitude. "I measured one of them," says Mr. Smeathman, "which was perfectly cylindrical, and thirteen inches in diameter." These subterraneous passages are thickly lined with the same kind of clay as that of which the hill is composed, ascend the internal part of the external shell in a spiral form, and, winding round the whole building up to the top, intersect and communicate with each other at different heights. From every part of these large galleries proceed a number of pipes, or smaller galleries, leading to different parts of the building. There are, likewise, a great many which lead downward, by sloping descents, three and four feet perpendicular under ground, among the gravel, from which the laboring termites select the finer parts, which, after being worked up in their mouths to the consistence of mortar, become that solid clay or stone of which their hills, and every apartment of their buildings, except the nurseries, are composed. Other galleries ascend and lead out horizontally on every side, and are carried under ground, but near the surface, to great distances. Suppose the whole of the nests within a hundred yards of a house were completely destroyed, the inhabitants of those at a greater distance will carry on their subterraneous galleries, and invade the goods and merchandise contained in it by sap and mine, unless great attention and circumspection are employed by the proprietor.

When a breach is made in one of the hills, the first object that attracts attention is the behavior of the soldiers, or fighting insects. Immediately after the blow is given, a soldier comes out, walks about the breach, and seems to examine the nature of the enemy, or the cause of the attack. He then goes into the hill, gives the alarm, and, in a short time, large bodies rush out as fast as the breach will permit. It is not easy to describe the fury these fighting insects discover. In their eagerness to repel the enemy, they frequently tumble down the sides of the hill, but recover themselves very quickly, and bite everything they encounter. This biting, joined to the striking of their forceps upon the building, makes a crackling or vibrating noise, which is somewhat shriller and quicker than the ticking of a watch, and may be heard at the distance of three or four feet. While the attack proceeds, they are in the most violent bustle and agitation. If they get hold of any part of a man's body, they instantly make their hooked jaws meet at the first stroke, and never quit their hold, but suffer themselves to be pulled away leg by leg, and piece after piece, without the smallest attempt to escape. On the other hand, if a person keeps out of their reach, and gives them no further disturbance, in less than half an hour they retire into the nest, as if they supposed the wonderful monster that damaged their castle had fled. Before the whole of the soldiers have got in, the laboring insects are all in motion, and hasten toward the breach, each of them having a quantity of tempered mortar in his mouth. This mortar they stick upon the breach as fast as they arrive, and perform the operation with so much despatch and facility, that, notwithstanding the immensity of their numbers, they never stop or embarrass one another. During this scene of apparent hurry and confusion, the spectator is agreeably surprised when he perceives a regular wall gradually arising and filling up the chasm. While the laborers are thus employed, almost all the soldiers remain within, except here and there one, who saunters about among six hundred or a thousand laborers, but never touches the mortar. One soldier, however, always takes his station close to the wall that the laborers are building. This soldier turns himself leisurely on all sides, and, at intervals of a minute or two, raises his head, beats upon the building with his forceps, and makes the vibrating noise formerly mentioned. A loud hiss instantly issues from the inside of the dome and all the subterraneous caverns and passages. That this hiss proceeds from the laborers is apparent; for, at every signal of this kind, they work with redoubled quickness and alacrity. A renewal of the attack, however, instantly changes the scene. On the first stroke, the laborers run into the many pipes and galleries, with which the building is perforated; and this they do so quickly that they seem to vanish; for in a few seconds all are gone, and the soldiers rush out as numerous and as vindictive as before. On finding no enemy, they return again leisurely into the hill; and very soon afterward the laborers appear, loaded as at first, as active and as sedulous, with soldiers here and there among them, who act just in the same manner, one or other of them giving the signal to hasten the business. Thus the pleasure of seeing them come out to fight or to work, alternately, may be obtained as often as curiosity excites, or time permits; and it will certainly be found, that the one order never attempts to fight, nor the other to work, let the emergency be ever so great.

It is exceedingly difficult to explore the interior parts of a nest or hill. The apartments which surround the royal chamber and the nurseries, and, indeed, the whole fabric, have such a dependence on each other, that the breaking of one arch generally pulls down two or three. There is another great obstacle, namely, the obstinacy of the soldiers, who dispute every inch of ground, and fight to the very last, wounding severely those who are engaged in the attempt, and sometimes obliging them to desist. Besides this, while the soldiers are engaged in defending the outworks, the laborers are barricading the way within, stopping up the different galleries and passages which lead to the various apartments, particularly the royal chamber, all the entrances to which they fill up so artfully as not to let it be distinguishable while it remains moist; and externally it has no other appearance than that of a shapeless lump of clay. It may be known, however, by its situation, and by the crowd of soldiers and laborers who assemble around and within it, to defend or perish with it. It is never abandoned, and, when taken out, is always found full, the attendants running in one direction around the queen with the utmost solicitude, some of them stopping at her head, as if to give her something, and others taking her eggs away from her and piling them carefully together in some part of the chamber.

CHAPTER XII. (W.)

RELATION OF ANIMALS TO MAN. — THEIR EDUCATION AND DOMESTICATION.

It is not easy to determine with certainty what is the original feeling excited in animals by the presence of man. Our ordinary experience would lead us to believe, that, for the most part, they spontaneously fear him; but there are many circumstances which indicate the contrary, and that they have no dread of him, more than of each other, till they have become acquainted with his power and his disposition to destroy them. The small and timid fly at his approach, as they do from others larger and stronger than themselves. The more formidable beasts of prey, when stimulated by hunger, attack him. But there are some facts which tend to show, that the other large animals neither fear nor molest him; that they are unmoved by his presence, and that this is the natural feeling where his power and disposition are unknown. The narratives of travellers afford various illustrations of this. Stetter, an early scientific explorer of the arctic regions, relates many characteristic traits of the arctic fox. "When asleep, they came and smelt of our noses to ascertain if we were really asleep. On our first arrival they bit off the noses, fingers, and toes of our dead, when we were preparing them for the grave, and thronged in such a manner about the sick and infirm, that it was with difficulty they could be kept off. Every morning these audacious animals were seen prowling about among the sea-lions and polar bears lying upon the strand, smelling at such as were asleep, to discover if some one were not dead. If so, all hands were at work to dissect it and carry it off. It often happens that the sea-lions in their sleep overlay their young; and, as if conscious of this fact, the foxes examined the whole herd, one by one, and, when so lucky as to find a dead cub, immediately dragged it away. As they would not suffer us to be at rest, by night or day, we became exasperated, and harassed them by every means we could devise. When we awoke in the morning, there always lay two or three that had been knocked on the head the preceding night; and I can safely affirm that, during my stay, I killed two hundred of these animals with my own hands. On the third day after my arrival, I knocked down with a club, within the space of three hours, upwards of seventy of them, and made a covering to my tent of their skins. With one hand we could hold to them a piece of flesh, and knock them down with a stick or an axe in the other."

The same observer describes similar traits in several species of seal. They manifested no disturbance at the presence of man, suffered him to seize and handle their young, and lay down quietly in his neighborhood, apparently watching his proceedings. This fearlessness does not arise from any want of courage or spirit. Among themselves the fiercest contests are carried on, sometimes between individuals and sometimes between large herds. Stetter witnessed a battle between two of them which lasted three days, and until one had received no less than a hundred wounds.

Among the ferocious beasts of prey that inhabit warmer climates, the same ignorance of the power of man produces the same fearlessness, which, however, is exhibited in a different way. In the deserts of Africa, the lion, accustomed to conquer all other animals, even those superior to him in size and strength, has no fear of man, and no antipathy to him. When stimulated by hunger, he does not hesitate to approach him, and has been known singly to attack a whole caravan. But he has no mere thirst for blood. The same ignorance which prompts him at one time to attack man without fear, at another induces him to pass him unmolested, as he would any other helpless animal of the forest.

In some remote and unfrequented islands, the sea-fowl are so tame, that the crews of vessels walk around among them, and knock them down with sticks. An intelligent traveller describes the same characteristic as existing among some of the larger birds of prey. "Upon the highest point of the mountain," says he, "while my servants were refreshing themselves, after their toilsome ascent, with several dishes of boiled goat's flesh, this bird [a species of vulture] suddenly appeared. He did not stoop rapidly from a height, but came flying slowly along the ground, and sat down close to the meat, within the ring which the men had made around it. He stood for a moment as if to recollect himself, whilst the men ran for their weapons. Them he disregarded, for his attention was fixed upon the flesh alone. He first put his foot into the pan where there was a large piece of meat contained in some boiling water. Finding it a more uncomfortable sensation than he had expected, he let go the meat, and seeing two other pieces, a shoulder and a leg lying near by, he trussed them up in his claws, and carried them off. It was not many minutes before he came back again; and, although a great shout was set up to frighten him, he seemed not at all intimidated, but sat down within a few yards of the boiling meat, seeming inclined to make another attempt upon it. But, the party being now prepared for his reception, he was immediately shot."

How differently is man regarded where animals have been taught to feel his power. Upon our shores the seal has none of that fearlessness which it exhibits in Behring's Straits. The lion, that in the Desert of Sahara bids defiance to numbers, after he has lived for a few generations in the neighborhood of inhabited villages, learns to dread the power of man. He loses courage, flies from his voice, and sometimes yields even to women and children, who drive him from their cattle with clubs.

Some birds will distinguish between a person armed and one unarmed, and take the alarm accordingly. The sentinel of a flock of crows utters a warning cry as soon as the sportsman takes his gun from his shoulder. Many birds and small animals fly as soon as a man stoops down to pick up a stone. In general no fact is more familiar than the wildness of animals that live in districts frequented by man, although this wildness is accompanied by a less degree of courage and ferocity than in districts where he is not known.

A still greater though a different influence is exerted by man upon domesticated animals, and upon certain individuals belonging to species still wild, whom he has taken and educated. There is a great difference between the domestication of a species and the education of individuals. Some animals have lived with man from generation to generation in the domestic state, as the horse, the camel, and the ox. Others he has made captive and tamed and educated for a long period, and yet they have never become properly domesticated; such are the elephant among quadrupeds and the falcon among birds.

Some of the domesticated animals are not known to exist in the wild state except where they may be presumed to have escaped from human dominion, as the horse, ox, sheep, and camel. It is the belief of many, that these animals were an original gift from our Creator, and that we have always had them in our possession. There is no record of the period when they were subdued to our use. Their services indeed seem to have been necessary to the progress of the race. It is by the substitution of their labor for that of man, that the first step is made in the improvement of his condition. They seem absolutely necessary to any considerable progress in refinement and civilization. Without them, his whole labor would be required for the supply of his mere physical necessities; but, by availing himself of theirs, he procures sufficient leisure for higher occupations. At the present day, the employment, or, so to speak, the domestication of mere physical agents, wind, water, steam, and electricity, seems destined to operate in a similar manner to aid his future progress.

The animals which have thus been subdued to the service of man are, in the different regions of the earth, precisely those which are adapted to his necessities and convenience in those regions. The Laplander has the reindeer, formed to tread with ease amid snow and ice, and able to find his support from the scanty vegetable productions of his inhospitable climate. In the fertile countries of the temperate zone we find the horse, formed to move upon the turf and subsist upon grain and the choicest herbs; while in the regions around the equator the camel flourishes upon a miserable diet, is able to endure a long abstinence from water and food, and to travel with comparative ease across deserts of sand. Other animals undergo changes in their characteristics according to the climate whither they follow their master. The dog, his friend as well as servant, changes his form, his character, and his constitution as he accompanies him: whilst the sheep, valuable both for its flesh and its fleece, adapts itself to his wants, and ceases to be covered with wool in those climates where warmth of clothing is no longer needed.

It seems probable that our domestic animals have all undergone some change in consequence of their intercourse with man. When they escape from his dominion and return to the wild state, in the course of some generations a manifest deterioration takes place in them; whilst there is a gradual improvement among those that remain subjected to his sway. It has been the habit of some to represent the wild horse as possessed of a nobler form and more generous qualities than the domesticated. This is the poetical and romantic side of the matter. Cool and judicious observers, on the contrary, represent him, with some exceptions, as far inferior to the domestic animal in every particular except hardihood. His head is large, his form clumsy, his gait awkward. The varieties in the domestic race show how great an influence the circumstances in which the animal is placed may have had upon his qualities. Compare for instance the large English dray-horse with the diminutive pony; and the cart-horse with the racer.

Domesticated animals are sometimes educated, as the horse, the ox, and the dog. Others are not, as the hog, the cat, the rabbit, and the common fowl. Long association with man produces certain influences upon the habits of animals in a course of generations, but this is far short of the education of which they are capable when specially cared for, whether domestic or wild. We are all familiar with the perfect training which may be given to horses, elephants, dogs, and monkeys, and even to goats and pigs. It has been reported, that, among the ancients, lions have been yoked to triumphal cars, and been conducted to battle or to the chase ; and in modern times they have been subdued to a degree of docility which seems almost inconsistent with their native ferocity.

A celebrated French lady trained a number of mice, so that she could yoke them to a little chariot, and make them draw it for her amusement. A German made the same attempt upon half a dozen of the common brown rats. He taught them to go through a variety of evolutions at the word of command, and their exhibition was concluded by a sort of sham-fight among them. Seals have been sometimes made very tame and tractable. The beaver has been taught to fish and bring home his prey ; to accompany men and dogs in a boat, jump into the water, and return with fish in his mouth ; but, in all such cases, the education is confined to the individual, and does not, as in the case of the horse, ass, ox, and camel, extend to the race.

The education of birds has never been carried to the same extent as that of quadrupeds, partly because from their conformation they are not capable of assisting man in his labors, and partly because from their inferior capacity they cannot so readily be made to comprehend or obey his instructions. Still with due perseverance much may be taught them. A bird of South America, called the *agami*, has been taught to caress its master, to follow him in the house and the street, and to attack beggars and strangers, in the same way with dogs. The crow is a very tractable bird, and will learn to know all the members of a family, to run to welcome them on their return after absence, and to open a door by alighting upon the latch. Mr. Wilson, the ornithologist, was informed by a person whose account he trusted, that he tamed a crow and kept it for some months. During its captivity it became very familiar, was very noisy and loquacious, and could repeat the names of several of the family. At length it deserted him and was forgotten. Eleven months afterward, while travelling in a distant place, a flock of crows passed over him, and one of them, separating itself from the rest, flew down and perched upon his shoulder. By his familiarity and chattering he at once recognized his old acquaintance. He had become too fond of liberty, however, to suffer his master to entrap him, and flew off to rejoin his companions. A farmer on Long Island, having once slightly wounded a wild goose, kept it alive and tamed it. The next spring it joined one of the flocks of its species, which was passing over, and was seen no more till the autumn, when it returned with two young ones. The whole were then secured and domesticated.

Buffon gives a remarkable account of the education of one of the buzzard species, a bird of prey. It became as docile and domestic as a cat or a dog. It would follow and caress its owner, drive all other birds of prey from his yard, and fight with and conquer all his cats and dogs. It had a singular antipathy to wigs and red caps. It would snatch them from the heads of those who wore them, and carry them up to the tops of the tallest trees. It distinguished between its master's poultry and all others'. The former it protected, the latter it treated very harshly.

The sport of falconry affords one of the most striking illustrations of the degree of perfection to which the training of birds has been carried; and, as the falcon is seldom caught young, the difficulty of the task is enhanced by the consequent development of his savage nature. It is first necessary to quell his ferocious spirit, to break down his violent temper. This is done by debarring him from food, by confinement, and sometimes by exposing him for some time in a blacksmith's shop to the continued clang of hammers. He is at the same time kept under the constant watch of the falconer, so as to become accustomed to his presence.

He is then taught to settle on the falconer's fist; to spring into the air when thrown off, and to return upon the signal of a whistle. This is effected by training him while tied by a long string, by which he can be made to return at will. Next, some food of which he is especially fond is attached to the stuffed figure of a bird, called a *lure*. This he is suffered to fly at, and at first to feed from it to satiety; but by and by he learns to return without feeding at all, on hearing the accustomed signal. When sufficiently accustomed to this exercise in confinement, he is hooded and taken into the field. As soon as the prey is sprung, the hood is taken off, and he is tossed into the air. He wheels round and round high above his victim, then pounces down, seizes it in his talons and bears it to his master, who always rewards him with a bit of the flesh.

Very large falcons have been taught to fly at the roebuck, the bear, the wolf, &c. They are made in the first instance to feed out of the sockets of the eyes of a stuffed figure of one of these animals. While the bird is eating, the figure is moved on, at first slowly, at last very rapidly by a horse at full speed, till the falcon has learned to fix himself very firmly to the skull, and to continue tearing out his food in spite of the motion. Hence, as soon as he is taken out to hunt, and is unloosed at any of these animals, he darts upon it, fixes himself upon its skull, and proceeds to tear out its eyes.

In the education of animals great patience and perseverance are required; and it is worthy of remark that little is accomplished by severity, as compared with kindness, gentleness, and indulgence. Punishments have less effect than rewards. The best success is obtained by establishing agreeable associations with the performance of the duty required. This is usually done at first by means of favorite articles of food. Sugar especially is much used for this purpose. Certain individuals appear to have a peculiar faculty for the training of animals, and in some instances the influence they acquire over them is almost mysterious. This is particularly the case in regard to the horse.

An appeal to the imitative propensity is of great use in the education of some animals. This propensity, though limited in range, is very perfect as far as it goes. It is of particular advantage with the monkey tribe among the Mammalia, and with the parrots and mocking-birds among Birds. Monkeys appear to possess upon the whole more intelligence, — that is to say, more power of understanding the purposes and motives of persons about them, of comprehending their signs and language, and of conducting themselves in conformity with their intentions, — than any other animal. It is not, that they have been taught so much as others to render essential services to man, — for they have been educated as often to mischief as to utility; — but it is their capacity for observation, their nice perception of the purpose of what is going on about them, and their power of comprehension and combination, which evince this superiority. Let them be as carefully educated to useful purposes as the dog, the horse, or the elephant, and, although they might prove less serviceable to mankind, they would probably give evidence of a higher degree of capacity. Even as their discipline has been managed, the catalogue of their accomplishments is by no means contemptible, and affords a good illustration of their capacity. They have been taught to dress themselves, to kindle a fire, to scour plate, to wash glasses, to make their own beds and wash out their apartments, to eat with a spoon, to dance to music on the tight rope, and to ride on horseback. A few tame apes who had watched the operations of some scientific observers, undertook to go through with all their motions themselves. One stationed himself at the telescope to look through it at the stars, another ran to the timepiece as if to count the time, whilst a third undertook to record their observations with a pen and ink.

The monkey and the parrot have each a complete appreciation of the nature and extent of their own powers, and do not attempt what they have not capacity to accomplish. They have a strong disposition to imitate, but the disposition in each takes a direction which is determined by the kind of organs they have for carrying it into effect. The monkey imitates the actions of man, but never his words. The parrot imitates his words, but never his actions.

This propensity in monkeys has been taken advantage of in a variety of ways. The Indians, when they wish to capture them, wash their own faces and hands in a basin of water in their sight, and then retire, leaving the basin filled with birdlime or some other adhesive substance. The animals, in attempting to perform the same operation, become entangled and blinded, and are then easily secured. In order to get the fruit upon the inaccessible branches of the cocoa-nut tree, the Indians pluck what is on the lower ones, and arrange it in heaps or circles upon the ground.

The monkeys immediately imitate the process, and do not desist till they have entirely stripped the tree. A Catholic priest, who indulged himself in the luxury of a pet monkey, was once followed by him to church, where, seating himself upon the sounding board over the preacher's head, he imitated in the most grotesque manner all his gestures, to the unrestrained amusement of his congregation. The priest, scandalized by their unseasonable levity, had recourse to reproof, and became quite animated and violent in his gesticulations. These, being all faithfully copied by the mimic over his head, only served to redouble the expressions of mirth which he sought to restrain.

The orang-outang, one of the largest of this tribe, and that which approaches the most nearly to man in his physical conformation, has been taught to perform many useful offices as a servant, to pound a mortar, to fetch water in a pitcher upon his head, to turn the spit and watch the roasting of meat, to assist in heating an oven and removing the embers from it, to ascend the rigging of a ship and help in managing the ropes. Buffon describes one which would give his hand to persons who came to visit him, and wait upon them to the door; would sit at table, unfold and manage his napkin, eat with a fork and spoon, pour out wine and drink a health, and pour out and sweeten a cup of tea. Another has been taught to pick his teeth with a toothpick, eat strawberries with a fork, holding the plate in one hand and the fork in the other, and to uncork a bottle of wine and drink it; and on one occasion he attempted to unlock his chain with a piece of stick, as he had seen his keeper do with a key.

In some countries, on account of their strange resemblance to mankind, monkeys have been held in some reverence, and have been the objects of a superstitious worship. In Ceylon a particular monkey's tooth, which was supposed to possess peculiar virtues, was valued at an enormous sum. Sanctuaries or places of refuge were allotted to them by the Brahmins. In one of the cities of the East, hospitals are said to have been established for them. In consequence of being held in this regard, they sometimes so increase in numbers and insolence, as to become extremely annoying to the inhabitants, who, however, feel bound to tolerate them from the belief, according to the doctrine of transmigration, that they are animated by the souls of their ancestors.

Could we find combined in a single animal the powers possessed by the monkey and the parrot, it would present indeed a very close, but still a very humiliating and distorted, resemblance to humanity. But the parrot, although by no means stupid when compared with many other birds, is yet far below the monkey, and in fact below many others of the Mammalia, in intelligence. The monkey understands language without being able to use it; the parrot uses it without being able to understand it; and as the monkey never attempts the imitation of words, the parrot never attempts to convey ideas by them.

The extent to which this propensity to imitate sounds may be cultivated is in some birds very great. It exists in many others beside the parrot tribe, and as to both articulate and inarticulate sounds. Birds with a round, thick tongue can be taught to repeat words, as the jays, jackdaws, magpies, and crows; whilst those with a thin, forked one are more capable of catching musical sounds, such as the cries of birds and animals, and the whistling of a man. Thus the canaries, linnets, and bullfinches are sometimes taught to repeat artificial airs. The powers of the American mocking-bird are the most remarkable and well known of this kind. The following graphic description of its performances is given by Wilson. "While thus exerting himself, a person destitute of sight would suppose that the whole feathered tribes had assembled together on a trial of skill, so perfect are his imitations. He many times deceives the sportsman, and sends him in search of birds that perhaps are not within miles of him, but whose notes he exactly imitates; even birds themselves, are frequently imposed upon by this admirable mimic, and are decoyed by the fancied call of their mates, or dive with precipitation into the depth of thickets at the scream of what they suppose to be the sparrow-hawk. The mocking-bird loses little of the power and energy of his song by confinement. In his domesticated state, when he commences his career of song, it is impossible to stand by uninterested. He whistles for the dog; Cæsar starts up, wags his tail, and runs to meet his master; he squeaks out like a hurt chicken, and the hen hurries about with hanging wings and bristling feathers, clucking to protect her injured brood. The barking of the dog, the mewing of the cat, the creaking of a passing wheelbarrow, follow with great truth and rapidity. He repeats the tune taught him by his master, though of considerable length, fully and faithfully. He runs over the quaverings of the canary, and the clear whistlings of the Virginian nightingale, or red-bird, with such superior execution and effect, that the mortified songsters feel their own inferiority, and become altogether silent, while he seems to triumph in their defeat by redoubling his exertions."

Parrots exhibit various degrees of tractability, and there are some which have not only the capacity of uttering articulate sounds, but a great disposition to exercise their powers and to make new acquirements. They are more easily taught by children than by adults; perhaps because, as an old writer remarks, the articulation of children is more imperfect and unequal, and more like that of which the bird itself is capable. But those who are well taught, will also imitate the voice, the laugh, and the cough of old persons. Their memory is very considerable, especially if cultivated when they are young. We are told of one which was purchased by a dignitary of the church for a hundred crowns, because it could repeat the Apostle's Creed correctly. Without being taught, they will often spontaneously catch and repeat phrases which they are in the habit of hearing; especially when they are pronounced with emphasis. Hence, when exposed in public places, they are very apt to learn the profane talk and vulgar oaths which they constantly hear. They can imitate the whistling of a few notes of a tune tolerably well, but not any continued melody; they have no true ear for music, and sing no airs of their own, like other birds.

The following is a remarkable example of the self-education of the imitative propensity in one of the liveliest and most melodious of our native birds, the bobolink, or rice-bird. One of them was confined in an apartment with a pair of canaries; but, while in a separate cage, he did not sing at all. Afterward, when placed in the same one with them, he began to attempt an imitation, but at first with little success. He watched them closely and strove to make the same notes; but, failing egregiously, he flew at them in anger, pecked at them, and drove them from their perch. After a perseverance of some weeks, he was able to learn a single note; and, after practising this for a time, mastered another. At length he completely acquired the song of the canaries, and sang with them in perfect harmony and time, always closing at the same note. Before he had made himself perfect, he waited till the canaries had struck the key-note, before he began himself; but after feeling confidence in his own powers, undertook always to give the signal himself by a significant *cluck*, and then his companions would strike in, and all would go on together.

During the period of this self-imposed pupilage he seemed to have forgotten his native music, and uttered no note of the bobolink. But, after practising with the canaries, he again attempted his own melody, at first imperfectly, mixing it with that of the canary; but at length, by careful practice, he regained the control over his original song. Then giving his directing cluck, whilst the canaries started off with their own peculiar song, he would accompany them with the notes of the bobolink; and so they continued afterward to sing together, each with its own music, but beginning and ending together.

'Of all quadrupeds, of whose history and manners we have any proper knowledge, the elephant is one of the most remarkable, both for docility and for understanding. He possesses all the senses in perfection; but in the sense of touch he excels all the brute creation. His trunk is the chief instrument of this sense. In an elephant fourteen feet high, the trunk is about eight feet long, and five feet and a half in circumference at the base. It is a large fleshy tube, divided through its whole extent by a septum or partition. It is capable of motion in every direction. The animal can shorten or lengthen it at pleasure. It answers every purpose of a hand; for it grasps large objects with great force, and its extremity can lay hold of a sixpence or even of a pin. The trunk of the elephant affords him the same means of address as the ape has. It serves the purposes of an arm and a hand. By this instrument, the elephant conveys large or small bodies to his mouth, places them on his back, embraces them fast, or throws them forcibly to a distance.

'When tamed and instructed by man, the elephant is soon rendered the mildest and most obedient of all domestic animals. He loves his keeper, caresses him, and anticipates his commands. He learns to comprehend signs, and even to understand the expression of sounds. He distinguishes the tones of command, of anger, and of approbation, and regulates his actions by his perceptions. The voice of his master he never mistakes; and executes his orders with alacrity, but without any degree of precipitation. His movements are always measured and sedate, and his character seems to correspond with the gravity of his mass. To accommodate those who mount him, he readily learns to bend his knees. With his trunk he salutes his friends, uses it for raising burdens, and assists in loading himself. He loves to be clothed, and seems to be proud of gaudy trappings. In the southern regions, he is employed in drawing wagons, ploughs, and chariots. "I was eye-witness," says P. Philippe, "to the following facts. At Goa there are always some elephants employed in the building of ships. I one day went to the side of the river, near which a large ship was building in the city of Goa, where there is a large area filled with beams for that purpose. Some men tie the ends of the heaviest beams with a rope, which is handed to the elephant, who carries it to his mouth, and, after twisting it round his trunk, draws them without any conductor, to the place where the ship is building, though it has only once been pointed out to him. He sometimes drew beams so large that more than twenty men would have been unable to move them. But what surprised me still more, when other beams obstructed the road, he elevated the ends of his own beams, that they might run easily over those which lay in his way. Could the most enlightened man do more?" When at work, the elephant draws equally, and, if properly managed, never turns restive. The man who conducts the animal generally rides on his neck, and employs a hooked iron rod, or a bodkin, with which he pricks the head, or sides of the ears, in order to push the creature forward, or to make him turn. But words are commonly sufficient. The attachment and affection of the elephant are sometimes so strong and durable that he has been known to die of grief, when, in an unguarded paroxysm of rage, he had killed his guide.

'In India, the domestic elephants, to whom the use of water is as necessary as that of air, are allowed every possible convenience for bathing themselves. The animal goes into a river till the water reaches his belly. He then lies down on one side, fills his trunk several times, and dexterously throws the water on such parts as happen to be uncovered. The master, after cleaning and currying one side, desires the animal to turn to the other, which command he obeys with the greatest alacrity; and, when both sides have been properly cleaned, he comes out of the river, and stands some time on the bank to dry himself. The elephant, though his mass be enormous, is an excellent swimmer; and, of course, he is of great use in the passage of rivers. When employed on occasions of this kind, he is often loaded with two pieces of cannon which admit three or four pound balls, beside great quantities of baggage and several men fixed to his ears and tail. When thus heavily loaded, he spontaneously enters the river and swims over, with his trunk elevated in the air for the benefit of respiration. He is fond of wine and ardent spirits. By showing him a vessel filled with any of these liquors, and promising him it as the reward of his labors, he is induced to exert the greatest efforts, and to perform the most painful tasks. The elephant is employed in dragging artillery over mountains, and, on these occasions, his sagacity and docility are conspicuous. Horses or oxen, when yoked to a cannon, make all their exertions to pull it up a declivity. But the elephant pushes the breech forward with his front, and at each effort supports the carriage with his knee, which he places against the wheel. He seems to understand what his *cornack*, or conductor, says to him. When his conductor wants him to perform any painful labor, he explains the nature of the operation, and gives the reasons which should induce him to obey. If the elephant shows a reluctance to the task, the cornack promises to give him wine, arrack, or any other article that he is fond of, and then the animal exerts his utmost efforts. But to break any promise made to him is extremely dangerous. Many cornacks have fallen victims to indiscretions of this kind. "At Dehan," says M. de Bussy, "an elephant, from revenge, killed its cornack. The man's wife, who beheld the dreadful scene, took her two children, and threw them at the feet of the enraged animal, saying, *Since you have slain my* *husband, take my life also, as well as that of my children.* The elephant instantly stopped, relented, and, as if stung with remorse, took the eldest boy in its trunk, placed him on its neck, adopted him for its cornack, and would never allow any other person to mount it."

'From the members of the Royal Academy of Sciences we learn some curious facts with regard to the manners of the Versailles elephant. This elephant, they remark, seemed to know when it was mocked, and remembered the affront till it had an opportunity of revenge. A man deceived it by pretending to throw some food into its mouth. The animal gave him such a blow with its trunk as knocked him down, and broke two of his ribs. A painter wanted to draw the animal in an unusual attitude, with its trunk elevated, and its mouth open. The painter's servant, to make it remain in this position, threw fruits into its mouth, but generally made only a feint of throwing them. This conduct enraged the elephant; and, as if it knew that the painter was the cause of this teasing impertinence, instead of attacking the servant, it eyed the master, and squirted at him from its trunk such a quantity of water as spoiled the paper on which he was drawing. This elephant commonly made less use of its strength than of its address. It loosed, with great ease and coolness, the buckle of a large double leathern strap, with which its leg was fixed; and as the servants had wrapped the buckle round with a small cord, and tied many knots upon it, the creature, with much deliberation, loosed the whole, without breaking either the strap or the cord.

'Next to the elephant, the dog seems to be the most docile quadruped. A wild dog is a passionate, ferocious, and sanguinary animal. But after he is reduced to a domestic state, these hostile dispositions are suppressed, and they are succeeded by a warm attachment, and a perpetual desire of pleasing. The perceptions and natural talents of the dog are acute. When these are aided by instruction, the sagacity he discovers, and the actions he is taught to perform, often excite our wonder.

'The shepherd's dog, independently of all instruction, seems to be endowed by nature with an innate attachment to the preservation of sheep and cattle. His docility is likewise so great, that he not only learns to understand the language and commands of the shepherd, and obeys them with faithfulness and alacrity, but, when at distances beyond the reach of his master's voice, he often stops, looks back, and recognizes the approbation or disapprobation of the shepherd from the mere waving of his hand. He reigns at the head of a flock, and his voice is better heard than that of his master. His vigilance and activity produce order, discipline, and safety. Sheep and cattle are peculiarly subjected to his management; which he prudently conducts and protects, and never employs force against them except for the preservation of peace and good order.

'Every person knows the docility and sagacity of such dogs as are employed in conducting blind mendicants. A blind beggar used to be led through the streets of Rome by a middle-sized dog. This dog, beside leading his master in such a manner as to protect him from all danger, learned to distinguish not only the streets, but the houses, where his master was accustomed to receive alms twice or thrice a week. Whenever the animal came to any of these streets, with which he was well acquainted, he would not leave it till a call had been made at every house where his master was usually successful in his petitions. When the beggar began to ask alms, the dog, being wearied, lay down to rest; but the master was no sooner served or refused, than the dog rose spontaneously, and, without either order or sign, proceeded to the other houses where the beggar generally received some gratuity. When a half-penny was thrown from a window, such was the sagacity and attention of this dog, that he went about in quest of it, lifted it from the ground with his mouth, and put it into his master's hat. Even when bread was thrown down, the animal would not taste it, unless he received a portion of it from the hand of his master. Without any other instruction than imitation, a mastiff, when accidentally shut out from a house which his master frequented, uniformly rung the bell for admittance. Dogs can be taught to go to market with money, to repair to a known butcher, and to carry home the meat in safety. They can be taught to dance to music, and to search for food, and find anything that is lost.

'There was a dog formerly belonging to a grocer in Edinburgh, which for some time amused and astonished the people in the neighborhood. A man, who went through the streets ringing a bell and selling penny pies, happened one day to treat this dog with a pie. The next time he heard the pie-man's bell, he ran to him with impetuosity, seized him by the coat, and would not suffer him to pass. The pie-man, who understood what the animal wanted, showed him a penny, and pointed to his master, who stood in the street-door, and saw what was going on. The dog immediately supplicated his master by many humble gestures and looks. The master put a penny into the dog's mouth, which he instantly delivered to the pie-man, and received his pie. This traffic between the pie-man and the grocer's dog was daily practised for several months.

'Mr. Ray, who wrote about the end of the seventeenth century, informs us, that he had seen a horse who danced to music, who, at the command of his master, affected to be lame, who simulated death, lay motionless with his limbs extended, and allowed himself to be dragged about, till some words were pronounced, when he instantly sprung up on his feet. Facts of this kind would scarcely receive credit, if every person were not now acquainted with the wonderful docility of the horses educated by public exhibitors of horsemanship. In exhibitions of this kind, the docility and prompt obedience of the animals deserve more admiration than the dexterous feats of the men.

'Animals of the ox kind, in a domestic state, are dull and phlegmatic. Their sensibility and talents seem to be very limited. But we should not pronounce rashly concerning the genius and powers of animals in a country where their education is totally neglected. In all the southern provinces of Africa and Asia, there are many wild bisons, or bunched oxen, which are caught young and tamed. They are soon taught to submit, without resistance, to all kinds of domestic labor. They become so tractable that they are managed with as much ease as our horses. The voice of their master is alone sufficient to make them obey, and to direct their course. They are shod, curried, caressed, and supplied abundantly with the best food. When managed in this manner, these animals appear to be different creatures from our oxen. The oxen of the Hottentots are favorite domestics, companions in amusements, assistants in all laborious exercises, and participate the habitation, the bed, and the table of their masters. As their nature is improved by the gentleness of their education, by the kind treatment they receive, and the perpetual attention bestowed on them, they acquire sensibility and intelligence, and perform actions which one would not expect from them. The Hottentots train oxen to war. In all their armies there are considerable troops of them, which are easily governed, and are let loose by the chief when a proper opportunity occurs. They instantly dart with impetuosity upon the enemy. They strike with their horns, kick, overturn, and trample under their feet everything that opposes their fury. They run ferociously into the ranks, which they soon put in the utmost disorder, and thus pave the way for an easy victory to their masters. They are likewise instructed to guard the flocks, which they conduct with dexterity, and defend them from the attacks of strangers and of rapacious animals. They are taught to distinguish friends from enemies, to understand signals, and to obey the commands of their masters. When pasturing, at the smallest signal from the keeper, they bring back and collect the wandering animals. They attack all strangers with fury; which renders them a great security against robbers. These *brackelays*, as they are called, know every inhabitant of the kraal, and discover the same marks of respect for all the men, women, and children, as a dog does for those who live in his master's house. These people may, therefore, approach their cattle with the greatest safety. But if a stranger, and particularly a European, should use the same freedom, without being accompanied by one of the Hottentots, his life would be in imminent danger.'

The influence of education is, however, by no means confined to the animals of the higher orders. Reptiles, Fishes, and even Insects have also been trained and domesticated. In Ceylon, the deadly Cobra has been sometimes tamed and trained to perform certain services. He has been kept as an inmate of the house, moving about freely with the members of the family. In one household, near Negombo, a wealthy individual, who kept large sums of money at home, employed them instead of dogs, as protectors. They glided about his apartments, a terror to thieves, but harmless to all others. Fishes, toads, and spiders, have been taught to come at a given signal for food, and fleas have been educated to endure a harness, and perform various curious evolutions.

Wonderful accounts have been given of the serpent-charmers of the East, and it has been generally believed that they have some peculiar power hereditary in certain families, by which they are able to handle and play with, and even to irritate, the most venemous of the race without injury. That this is constantly done there is no doubt, but there have been different opinions as to the mode. Some writers have asserted that the poisonous fangs are always extracted before the animals are handled. An exhibition of this kind was given at the Zoölogical Gardens in London a few years ago, and the disclosures of the performers appear to favor this view of the question. The following brief sketch is condensed from a published and apparently authentic narrative. The exhibitors were an old man and his son-in-law Mohammed, a mere lad of sixteen. "The lad, with his arms bared, first seizes by the tail a large Cobra de Capello, a hooded snake of the most poisonous kind, and holding him at arm's length allows him to writhe about for some time, till he is in a state of high irritation. He is pinched and teased in various ways, and repeatedly strikes at the hands, arms, and legs of his assailant, but the blows are all avoided with great agility. Another larger and fiercer is then seized in the same way, and is buffeted about the head with the open hand till he is quite furious and seizes the lad on the arm; but, merely wiping the spot, the boy proceeds to tie the animal about his neck, and also into a variety of knots. He then tells him to be quiet, and lays him on his back, gently stroking his neck and skin. He remains as if quite dead, and a third is carried through the same process, and then placed in the bosom next the skin, where he coils quite around the body of the exhibitor, and is withdrawn only with great difficulty and in a state of great irritation."

Upon a strict examination of the persons making this exhibition, they admitted that the fangs were always previously removed, and that without this precaution no one would venture upon such freedom with these deadly reptiles. They described the manner of catching and preparing their subjects, and it is in this part of the process that the peculiar skill and courage of the serpent-charmers is shown.

But, in contradiction to this statement, we have the assertion of many travellers who have witnessed these exhibitions in the East, that the fangs are not extracted, that they have examined the animals thus exhibited, and that, at the same time that they were thus completely under the influence of the charmers and incapable of doing them any injury, their bite was as destructive as ever to the life of other animals exposed to them. Dr. John Davy, in his account of Ceylon, is certain that the only charm exerted is that of courage and confidence. Bruce, the celebrated Egyptian traveller, gives his testimony to the same effect, and more lately Tennent confirms the same statement.

CHAPTER XIII. (S.)

OF THE ARTIFICES OF ANIMALS.

'The Monkey tribes are among the most remarkable of animals, for their various indications of cunning, artifice, and even intelligence. Others may sometimes exhibit a greater amount of actual, practical wisdom, but there are none which present a nearer approach in certain respects to the human character, or a more close imitation of some of the lower faculties, propensities, and manners of our own species. Their peculiarities will be best illustrated by a variety of examples.'

Margraaf informs us, that the monkeys in Brazil, while they are sleeping on the trees, have uniformly a sentinel to warn them of the approach of the tiger or other rapacious animals; and that, if ever this sentinel is found sleeping, his companions instantly tear him in pieces for his neglect of duty. For the same purpose, when a troop of monkeys are committing depredations on the fruits of a garden, a sentinel is placed on an eminence, who, when any person appears, makes a certain chattering noise, which the rest understand to be a signal for retreat, and immediately fly off and make their escape.

'Mr. Parkyns in his late travels in Abyssinia states many interesting particulars concerning them.

'"You see them," he says, "quarrelling, making love; mothers taking care of their children, combing their hair; and the passions, jealousy, anger, love, are as distinctly marked as among men. They have a language apparently as intelligible to one another as ours; and in this they scold at, and dispute with, each other, as earnestly as we do.

'"The monkeys, especially the cynocephali, have their chiefs, whom they implicitly obey, and a regular system of tactics in war, pillaging, robbing orchards, &c. These forays are managed with the utmost regularity. A tribe coming down to feed from their village in the mountains, which is usually a cleft in the face of some cliff, brings with it all its members. The elders of the tribe, distinguished by the quantity of mane which covers their shoulders, take the lead, peering cautiously over the precipices, and pausing at each elevation to take a survey of the road before them. Others are posted as scouts, in flank and rear, who are equally vigilant, and call out at times, as if to keep order among the motley group that constitutes the main body, or to give notice of some real or fancied danger.

'"The main body is composed of the young people of the tribe and the females. The small children are carried on their mothers' backs. Unlike the dignified march of the leaders, the rabble go along in a most disorderly manner, trotting on and chattering heedlessly, trusting entirely to the vigilance of their scouts. The young linger behind to pick berries from some tree; the mothers delay now and then, to feed, or caress, or dress the hair of their offspring; and the younger females, apparently provoked by each other's cries or gestures, pinch, scratch, and bite one another, till a loud bark of command from one of the chiefs calls them to order. A single cry of alarm makes them all halt and remain on the alert; till another in a different tone reassures them, and they then proceed on their march.

'"Arrived at the cornfields, the scouts take their position on the eminences all around, while the remainder of the tribe collect provision with the utmost expedition. They fill their cheek-pouches as full as they can hold, and then tuck the heads of corn under their armpits. Now there must be afterward a division of the collected spoil according to some established principle, or else how do the scouts feed? for they never quit for a moment their post of duty till it is time for the tribe to return, or till some indication of danger renders a retreat necessary.

'"They show great sagacity in searching for water, discovering at once the places where it is most readily found in the sand, and then digging for it with their hands, just as men would, and relieving one another in the work if the labor prove too great."

'The following anecdote serves to illustrate their singular adroitness and cunning. A showman, who had several to exhibit, gave Mr. Parkyns an opportunity of witnessing the tricks of one of them, who was a most dexterous thief, and managed always to steal food enough for his own support. His keeper led him to a spot near a date-seller who was sitting upon the ground with his basket beside him, and then put him through his usual evolutions. He kept a watchful eye upon the fruit; but so completely did he disguise his intentions, that a careless observer would never have noticed it. He did not at first appear to care about approaching the basket, but gradually brought himself nearer and nearer, till he got quite close to the owner. In the middle of one of his feats, he suddenly started up from the ground, on which he was lying stretched out like a corpse, and, uttering a cry as of rage or pain, fixed his eyes full at the face of the date-seller, and then, without moving the rest of his body, stole as many dates as he could hold in one of his hind hands, and popped them into his cheek-pouches, his victim knowing nothing of his loss, till informed of it by the laugh of the bystanders at his expense, in which he heartily joined. At this moment a boy in the crowd pulled the animal sharply by the tail. Conscience-stricken, as it were, he imagined the insult to have come from the man he had robbed, and fell upon him at once with great fury, and would have bitten him severely, except for the interference of his master.

'Their strong imitative propensity was exhibited to Mr. Parkyns in a curious and rather costly manner. He had been observed by one of them, in reading a book, to turn over its leaves in rapid succession as he went on with it. The monkey obtained the volume; and, sitting down to imitate him, as he turned each leaf, he tore it down from top to bottom.

'The exhibitor of a monkey laid a wager with the owner of a fierce English bull-dog, that the monkey would kill the dog in less than ten minutes, with no other weapon than a small oaken ferule. His master putting it into his hand, tossed him into the ring, saying, "Look out for that dog." The ferocious animal sprang at him, the bystanders expecting nothing but that he would tear his feeble adversary to pieces at once. The monkey, however, leaped several feet into the air, alighted upon the dog's back, seized him by the neck, and beat him to death in a few moments.

'A monkey was in the habit of riding his owner's hogs, especially one to which he was particularly partial. He would leap upon its back with his face towards its tail, and, whipping it unmercifully, drive it about till it could run no longer. The hogs lived under such terror of their tormenter, that, when he first came abroad in the morning, they set up a great cry at the sight of him. A person having a very vicious horse, that no one could ride, was advised to put the animal upon him. A pad was placed on his back, and the monkey upon it, with a switch in his hand, which he applied in the most vigorous manner. The horse immediately began kicking and galloping, but the monkey kept his seat and exercised his switch. The horse lay down upon the ground; but, when he threw himself on one side, the monkey was up on the other. He ran into a wood to brush him off; but, if a tree or bush occurred on one side, the monkey slipped to the other. At last the poor victim was so sickened, fatigued, and broken-spirited, that he ran home to the stable for protection. When the monkey was dismounted, a boy was placed upon the horse, who managed him with ease, and he gave no trouble afterward!'

The Deer kind are remarkable for the arts they employ in order to deceive the dogs. With this view the stag often returns twice or thrice upon his former steps. He endeavors to raise hinds or younger stags to follow him, and draw off the dogs from the immediate object of their pursuit. If he succeeds in this attempt, he then flies off with redoubled speed, or springs off at a side, and lies down on his belly to conceal himself. When in this situation, if by any means his foot is recovered by the dogs, they pursue him with more advantage, because he is now considerably fatigued. No other resource is now left him but to fly from the earth which he treads, and go into the waters, in order to cut off the scent from the dogs, when the huntsmen again endeavor to put them on the track of his foot. After taking to the water, the stag is so much exhausted that he is incapable of running much farther, and is soon *at bay*, or, in other words, turns and defends himself against the hounds. In this situation he often wounds the dogs, and even the huntsmen, by blows with the horns, till one of them cuts his hams to make him fall, and then puts a period to his life.

The fallow-deer are more delicate, less savage, and approach nearer to the domestic state than the stag. They associate in herds, which generally keep together. When great numbers are assembled in one park, they commonly form themselves into two distinct troops, which soon become hostile, because they are both ambitious of possessing the same part of the inclosure. Each of these troops has its own chief or leader, who always marches foremost, and he is uniformly the oldest and strongest of the flock. The others follow him; and the whole draw up in order of battle, to force the other troop, who observe the same conduct, from the best pasture. When hunted, they run not straight out, like the stag, but double, and endeavor to conceal themselves from the dogs by various artifices, and by substituting other animals in their place. When fatigued and heated, however, they take the water, but never attempt to cross such large rivers as the stag does.

The roe-deer is inferior to the stag and fallow-deer, both in strength and stature; but he is endowed with more gracefulness, courage, and vivacity. His eyes are more brilliant and animated. His limbs are more nimble; his movements are quicker, and he bounds with equal vigor and agility. He is, likewise, more crafty, conceals himself with greater address, and derives superior resources from his instincts. Though he leaves behind him a stronger scent than the stag, which increases the ardor of the dogs, he knows how to evade their pursuit, by the rapidity with which he commences his flight, and by numerous doublings. He delays not his arts of defence till his strength begins to fail him; for he no sooner perceives that the efforts of a rapid flight have been unsuccessful, than he repeatedly returns upon his former steps; and after confounding, by these opposite motions, the direction he has taken, after intermixing the present with the past emanations of his body, he, by a great bound, rises from the earth, and, retiring to a side, lies down flat upon his belly. In this immovable situation, he often allows the whole pack of his deceived enemies to pass very near him. The roe-deer differs from the stag in disposition, manners, and in almost every natural habit. Instead of associating in herds, they live in separate families. The two parents and the young go together, and never mingle with strangers. When threatened with danger, the mother hides her young in a close thicket; and so strong is her parental affection, that, in order to preserve them from destruction, she presents herself to be chased.

'The American panther has a mortal foe in the black bear, and a deadly strife occurs when they encounter each other. The deer, when pursued by the panther, sometimes avails itself of its knowledge of this enmity, and cunningly leads its pursuer into the very jaws of his foe. An instance is related of the remarkable adroitness exhibited on one occasion by the weaker animal, who, when hotly followed by the panther, and nearly exhausted, discovered the retreat of one of these bears, and, after some doubling, made directly for him, but, measuring well her distance, leaped clear over him, leaving the panther, who was directly at her heels, to fall a victim to his natural enemy.'

Hares form seats, or nests, on the surface of the ground, where they watch, with the most vigilant attention, the approach of any danger. In order to deceive, they conceal themselves between clods of the same color with their own hair. When pursued, they first run with rapidity, and then double or return upon their former steps. From the place of starting, the females run not so far as the males; but they double more frequently. Hares hunted in the place where they are brought forth, seldom remove to a great distance from it, but return to their form; and when chased two days successively, on the second day they perform the same doublings they had practised the day before. When hares run straight out to a great distance, it is a proof that they are strangers. "I have seen a hare," Fouilloux remarks, "so sagacious, that, after hearing the hunter's horn, he started from his form, and, though at the distance of a quarter of a league, went to swim in a pool, and lay down on the rushes in the middle of it, without being chased by the dogs. I have seen a hare, after running two hours before the dogs, push another from his seat, and take possession of it. I have seen others swim over two or three ponds, the narrowest of which was eighty paces broad. I have seen others, after a two hours' chase, run into a sheepfold, and lie down among its occupants. I have seen others, when hard pushed, run in among a flock of sheep, and they would not leave them. I have seen others, after hearing the noise of the hounds, conceal themselves in the earth. I have seen others run up one side of a hedge, and return by the other, when there was nothing else between them and the dogs. I have seen others, after running half an hour, mount an old wall six feet high, and clap down in a hole covered with ivy. Lastly, I have seen others swim over a river, of about eighty paces broad, oftener than twice, in the length of two hundred paces."

The Fox has, in all ages and nations, been celebrated for craftiness and address. Acute and circumspect, sagacious and prudent, he diversifies his conduct, and always reserves some art for unforeseen accidents. Though nimbler than the wolf, he trusts not entirely to the swiftness of his course. He knows how to insure safety by providing himself with an asylum, to which he retires when danger appears. He is not a vagabond, but lives in a settled habitation, and in a domestic state. The choice of situation, the art of making and rendering a house commodious, and of concealing the avenues which lead to it, imply a superior degree of sentiment and reflection. The fox possesses these qualities, and employs them with dexterity and advantage. He takes up his abode on the border of a wood, and in the neighborhood of cottages. Here he listens to the crowing of the cocks and the noise of the poultry. He scents them at a distance. He chooses his time with great judgment and discretion. He conceals both his route and his design. He moves forward with caution, sometimes even trailing his body, and seldom makes a fruitless expedition. When he leaps the wall, or gets in underneath it, he ravages the court-yard, puts all the fowls to death, and then retires quietly with his prey, which he either conceals under the herbage, or carries off to his kennel. The young hares he hunts in the plains, seizes old ones in their seats, digs out the rabbits in the warrens, finds out the nests of partridges, quails, &c., seizes the mothers on the eggs, and destroys a prodigious number of game. Dogs of all kinds spontaneously hunt him. When pursued, he runs to his hole; and it is not uncommon to send in terriers to detain him till the hunters remove the earth above, and either kill or seize him alive. The most certain method, however, of destroying a fox is to begin with shutting up the hole, to station a man with a gun near the entrance, and then to search about with the dogs. When they fall in with him, he immediately makes for his hole. But, when he comes up to it, he is met with a discharge from the gun. If the shot misses him, he flies off at full speed, takes a wide circuit, and returns to the hole, where he is fired upon a second time; but, when he discovers that the entrance is shut, he darts away straight forward, with the intention of never revisiting his former habitation. He is next pursued by the hounds, whom he seldom fails to fatigue; because, with much cunning, he passes through the thickest part of the forest, or places of the most difficult access, where the dogs are hardly able to follow him; and, when he takes to the plains, he runs straight out, without either stopping or doubling. But the most effectual way of destroying foxes is to lay snares baited with live pigeons, fowls, &c. The fox is an exceedingly voracious animal. Besides all kinds of flesh and fish, he devours, with equal avidity, eggs, milk, cheese, fruits, and particularly grapes. He is so extremely fond of honey that he attacks the nests of wild bees. They at first put him to flight by numberless stings; but he retires for the sole purpose of rolling himself on the ground, and of crushing the bees. He returns to the charge so often that he obliges them to abandon the hive, which he soon uncovers, and devours both the honey and the wax.

Birds have such an antipathy against him, that they no sooner perceive him than they send forth shrill cries to advertise their neighbors of the enemy's approach. The jays and blackbirds, in particular, follow him from tree to tree, sometimes two or three hundred paces, often repeating the watch-cries. The Count de Buffon kept two young foxes, which, when at liberty, attacked the poultry; but, after they were chained, they never attempted to touch a single fowl. A living hen was then placed near them for whole nights; and, though destitute of victuals for many hours, in spite of hunger and opportunity, they never forgot that they were chained, and gave the hen no disturbance.

In Kamtschatka, the animals called *Gluttons* employ a singular stratagem for killing the fallow-deer. They climb up a tree, and carry with them a quantity of that species of moss of which the deer are very fond. When a deer approaches near the tree, the glutton throws down the moss. If the deer stops to eat the moss, the glutton instantly darts upon his back, and, after fixing himself firmly between the horns, tears out his eyes, which torments the animal to such a degree, that, whether to put an end to its torments, or to get rid of its cruel enemy, it strikes its head against the tree till it falls down dead. The glutton divides the flesh of the deer into convenient portions, and conceals them in the earth to serve for future provisions. The gluttons on the river Lena kill horses in the same manner.

There are several species of rats in Kamtschatka. The most remarkable kind is called *Tegulchitch* by the natives. They make neat and spacious nests under ground, which they line with turf, and divide into different apartments, in which they deposit stores of provisions for supporting them during the winter. It is worthy of remark, that they never touch the provisions laid up for the winter, except when they cannot procure nourishment anywhere else. These rats, like the Tartars, change their habitations. Sometimes they totally abandon Kamtschatka for several years, and their retreat greatly alarms the inhabitants, which they consider as a presage of a rainy season, and of a bad year for hunting. Their return is, of course, looked upon as a good omen. They always take their departure in the spring, when they assemble in prodigious numbers, and traverse rivers, lakes, and even arms of the sea. After they have made a long voyage, they frequently lie motionless on the shore, as if they were dead. When they recover their strength, they recommence their march. They generally return to Kamtschatka about the month of October; and they are sometimes met with in such prodigious numbers, that travellers are obliged to stop hours till the whole troop passes.

With regard to Birds, their artifices are not less numerous nor less surprising than those of quadrupeds. The eagle and hawk kinds are remarkable for the sharpness of their sight, and the arts they employ in catching their prey. Their movements are rapid or slow, according to their intentions, and the situation of the animals they wish to devour. Rapacious birds uniformly endeavor to rise higher in the air than their prey, that they may have an opportunity of darting forcibly down upon it with their pounces. To counteract these artifices, Nature has endowed the smaller and more innocent species of birds with many arts of defence. When a hawk appears, the small birds, if they find it convenient, conceal themselves in hedges or brushwood. When deprived of this opportunity, they often, in great numbers, seem to follow the hawk, and to expose themselves unnecessarily to danger, while in fact, by their numbers, their perpetual changes of direction, and their uniform endeavors to rise above him, they perplex him to such a degree that he is unable to fix upon a single object; and, after exerting all his art and address, he is frequently obliged to relinquish the pursuit. When in the extremity of danger, and after employing every other artifice in vain, small birds have been often known to fly to men for protection. This is a plain indication that these animals, though they in general avoid the human race, are by no means so much afraid of man as of rapacious birds.

Ravens often frequent the sea-shores in quest of food. When they find their inability to break the shells of mussels, &c., to accomplish this purpose they use a very ingenious stratagem. They carry a mussel, or other shell-fish, high up in the air, and then drop it down upon a rock, by which means the shell is broken, and they obtain the end they had in view.

'We are told of a Crow, who, desirous of getting possession of a bone which a dog, chained to his cabin, was quietly gnawing in front of it, attempted by various tricks and grimaces to divert his attention so that he might seize it. Failing in this, he flew away, and returned with another. The second comer suddenly darted down and struck the dog upon the spine. Irritated, and turning upon his assailant, he dropped the bone. This was immediately seized upon by the ingenious thief, who then flew away with his companion to enjoy their booty.

'A small bird of the hawk kind, called the Nine-killer, has been observed at particular seasons of the year to catch grasshoppers, beetles, or other insects, kill them, and stick them in a position entirely natural, upon the branches of trees or bushes, so that they appear, at first sight, as if alive. It is a common opinion where this bird is found, that it thus destroys nine insects every day, and hence its name; but, as it is known not to feed upon insects itself, but principally upon small quadrupeds and birds, the object of this expedient is not perfectly obvious. Some have supposed that it is done merely for amusement. The most probable explanation, however, is, that the insects are intended by this little hawk as a decoy for the birds which it designs for its prey. This manœuvre is put in practice in the fall of the year, just before the severe frosts begin, which by killing the insects deprive the smaller birds of the food on which they have been accustomed to subsist. They are of course, in the season of scarcity, led to the bait their sagacious enemy has provided, and thus become an easy prey.'

Of the economy of the inhabitants of the water, our knowledge is extremely limited. But, as the ocean exhibits a perpetual and general scene of attack and defence, the arts of assault and of evasion must, of course, be exceedingly various. For the preservation of some species of fishes, Nature has armed them with strong and sharp pikes. Others, as the perch kind, are defended by strong, bony rays in their fins. Others, as the univalve shell-fish, retire into their shells upon the approach of danger. The bivalves and multivalves, when attacked, instantly shut their shells, which, in general, is a sufficient protection to them. Some univalves, as the limpet kind, attach themselves so firmly, by excluding the air, to rocks and stones, that, unless quickly surprised, no force inferior to that of breaking the shell can remove them.

Several fishes, and particularly the salmon kind, when about to generate, leave the ocean, ascend the rivers, deposit their eggs in the sand, and, after making a proper *nidus* for their future progeny, return to the ocean from whence they came. Others, as the herring kind, though they seldom go up rivers, assemble in myriads from all quarters, and approach the shores, or ascend arms of the sea, for the purpose of continuing the species. When that operation is performed, they leave the coasts, and disperse in the ocean, till the same instinctive impulse forces them to observe similar conduct the next season.

The insect tribes, though comparatively diminutive, are not deficient in artifice and address. With much art the Spider spins his web. It serves him the double purpose of a habitation, and of a machine for catching his food. With incredible patience and perseverance, he lies in the centre of his web for days, and sometimes for weeks, before an ill-fated fly happens to be entangled. One species of spider, which is small, of a blackish color, and frequents cottages or outhouses, I have known to live, during the whole winter months, almost without the possibility of receiving any nourishment; for, during that period, not a fly of any kind could be discovered in the apartment. If they had been in a torpid state, like some other animals, the wonder of their surviving the want of food so long would not have been so great. But in the severest weather, and through the whole course of the winter, they were perfectly active and lively. Neither did they seem to be in the least emaciated.

The *Formica-leo*, or Ant-lion, is a small insect, somewhat resembling a wood-louse, but larger. Its head is flat, and armed with two fine movable crotchets, or pincers. It has six legs, and its body, which terminates in a point, is composed of a number of membranous rings. In the sand, or in finely-pulverized earth, this animal digs a hole in the form of a funnel, at the bottom of which it lies in ambush for its prey. As it always walks backward, it cannot pursue any insect. To supply this defect, it lays a snare for them, and especially for the ant, which is its favorite food. It generally lies concealed under the sand in the bottom of its funnel or trap, and seldom exhibits more than the top of its head. In digging a funnel, the ant-lion begins with tracing a circular furrow in the sand, the circumference of which determines the size of the funnel, which is often an inch deep. After the first furrow is made, the animal traces a second, which is always concentric with the first. It throws out the sand as with a shovel, from the successive furrows or circles, by means of its square, flat head, and one of its fore legs. It proceeds in this manner till it has completed its funnel, which it does with surprising promptitude and address. At the bottom of this artful snare, it lies concealed and immovable. When an ant happens to make too near an approach to the margin of the funnel, the sides of which are very steep, the fine sand gives way, and the unwary animal tumbles down to the bottom. The ant-lion instantly kills the ant, buries it under the sand, and sucks out its vitals. It afterwards pushes out the empty skin, repairs the disorder introduced into its snare, and again lies in ambush for a fresh prey.

A spider, of that kind which carries her eggs in a bag attached to her belly, was thrown into the funnel of an ant-lion. The latter instantly seized the bag of eggs, and endeavored to drag it under the sand. The spider, from a strong love of offspring, allowed its own body to be carried along with the bag. But the slender silk by which it was fixed to the animal's belly broke, and a separation took place. The spider immediately seized the bag with her pincers, and exerted all her efforts to regain the object of her affections. But these efforts were ineffectual; for the ant-lion gradually sunk the bag deeper and deeper in the sand. The spider, however, rather than quit her hold, allowed herself to be buried alive. In a short time, the observer removed the sand, and took out the spider. She was perfectly unhurt; for the ant-lion had not made an attack upon her. But, so strong was her attachment to her eggs, that, though frequently touched with a twig, she would not leave the place which contained them.

When arrived at its full growth, the ant-lion gives up the business of an ensnaring hunter. He deserts his former habitation, and crawls about for some time on the surface of the earth. He at last retires under the ground, spins a round silken pod, and is soon transformed into a fly.

CHAPTER XIV. (W.)

ASSOCIATION OF ANIMALS.

The principle of association in man is different in its development from that which is observed in all other animals, in so far as it is progressive in him, and stationary in them. Man has, no doubt, a social or gregarious instinct, which leads him to love and to seek the company of his fellows. But the form which his associations assume, the purposes they accomplish, the manner in which they are carried on, vary according to the circumstances in which he is placed. What are more unlike than the habitations, the food, the dress, the manners, and the habits of a savage in the interior of Australia, and those of the refined inhabitants of the cities of Europe? The beaver builds and lives for the most part in the same way; he is precisely where he was when first known to man. The bee and the ant, perfect as their societies are for to the purposes of their peculiar existence, know and seek no improvement.

In man, then, the tendency is instinctive, but its development is entirely dependent upon observation, experience, reason, and feeling; its development differs, therefore, in every tribe and every nation. In animals, the tendency and the development are both instinctive; and the mode of development is, consequently, nearly identical, and never progressive.

The disposition of animals to associate with each other varies in degree and as to the objects to which it is directed. Some only associate for the purpose of continuing the species, and no personal relation exists between different individuals. Others connect themselves in pairs for the same object. Some are gregarious from apparently a simple love of companionship, and with this feeling even those of different species will sometimes attach themselves to each other. There are those that collect together in flocks for the purpose of attack or defence; those that are combined together in order to build common habitations, but that still maintain their individual liberty; and, still further, those that not only build a common habitation, but constitute a community having regular institutions, a subordination of ranks, a division of labor, and a complete subservience of every individual to the general purposes of the state of which he constitutes a part.

The larger beasts of prey are unsociable and solitary. The lion associates with no other animal, seldom even with those of his own species. Some undoubted and interesting instances are recorded of his sparing small animals thrown into his cage, when he is himself a captive, and making them his companions. These are exceptions. Although by no means intrinsically sanguinary or ferocious, he has no love of society; he is, in his wild state, unapproachable, and loves to dwell and hunt by himself. The same is true of the tiger, the leopard, and others of the same description. But, among the carnivorous animals of the dog kinds, as the wolf and fox, as they are less powerful and courageous individually, we find a disposition to associate for certain purposes. It is ordinarily in concert that they attack large flocks of horses, deer, and sheep; but there is no other special bond of union among them, and no indication of an organized society.

Among many herbivorous quadrupeds the social disposition is strong, partly from the simple love of company, and partly for the purposes of common defence. Nearly all the larger animals of this kind, the elephant, horse, zebra, buffalo, bison, sheep, and deer, unite in large herds, and render themselves so formidable to beasts of prey, that it is only by stratagem and by picking up stragglers from the main body that any of them can be seized. Even the common sheep, proverbial as they have almost become for cowardice and stupidity, when they have been accustomed to feed in remote districts, beyond the protection of mankind, defend themselves with success against very formidable enemies. There is no animal which, in proportion to its size, is capable of inflicting a more severe blow than the male. The butt of the ram has even been known to overthrow the bull; the latter animal, by lowering his head too far, receiving the blow at a disadvantage. A single enemy will be thus disposed of; but, when attacked by numbers, as by a pack of wolves, the flock draws up into a compact body, with the young and weak in the centre, the stronger on the outside, and, thus arranged in a firm phalanx, it makes a formidable defence.

Among the smaller quadrupeds the social tendency is frequently very marked, but the object is not common defence. In many it is merely an instinctive preference for the society of their kind. Thus the vampire and spectre bats collect into flocks of prodigious numbers, but without any other apparent purpose.

But by others there is some more distinct object had in view, particularly the construction of common habitations. Such are the beaver, hamster, marmot, mole, and prairie dog. The numbers which thus assemble together are very large. A single farmer in Holland caught upon his own grounds more than five thousand hamsters. Their multiplication has sometimes been so great as to produce fears of a scarcity of grain. In a single town in Germany, where a premium was offered for their skins, eighty thousand were destroyed in one year. In our own country the most interesting example of this kind is in the prairie dog, already noticed. It is of a peaceable, accommodating, and most social disposition; for General Pike assures us he has seen the prairie dog, the rattlesnake, the pond frog, and the land tortoise, all take refuge in the same hole; to which motley company, the burrowing owl sometimes attaches himself.

The nobler birds of prey are solitary in their habits, and there is little society among them except what grows out of their relation to their offspring. The eagle and his mate appropriate a particular mountain or district to themselves, building their nest upon its most inaccessible spot. They hunt in company; one descends into the woods to frighten the small birds into the air, whilst the other sits upon some tree or rock to seize them as they rise. The vultures, on the contrary, collect in large bodies. Not that they prize society for its own sake. They simply collect together when the pursuit of some common object, such as the carcass of an animal or any collection of dead flesh, brings them together. Still so cowardly are they, even in large numbers, that a single eagle will sometimes keep them at bay, while he is satisfying his own hunger. Mr. Wilson relates, that, when thousands of the dead bodies of squirrels, which had been drowned in attempting to cross the Ohio, had been swept on shore by an eddy of the river, a bald eagle was seen feasting upon them alone, whilst a crowd of hungry vultures were perched on the trees in the neighborhood, waiting, as patiently as they could, till he had finished his repast.

Of other birds, a great many collect together in flocks, partly from the instinctive desire of the company of their kind, but often also for security from their enemies. This security is not attained by any direct combined resistance, for this would be unavailable either against the large rapacious birds or against man. But, by posting a watch to give warning of danger, they are able to feed and sleep in comparative safety. Implicit reliance is placed upon the sentinels, and it has been stated, that, if unfaithful to their trust, their companions fall upon them and put them to death. In the Shetland Isles the number of sea-fowl is so great that their capture is made a profitable occupation, and a curious stratagem is employed to evade the vigilance of their sentinel. The hunter approaches him cautiously, keeping behind some projecting crag, till he is very near. Then from his place of concealment he continues to throw drops of water into his face. Annoyed by the disagreeable sensation, which he is supposed to attribute to rain or the spray from the sea, he puts his head for protection under his wing as when going to sleep. The result is, that, like a man who shuts his eyes and lies down, he actually does sleep. The hunter at once wrings his neck, and then proceeds to despatch his companions.

Some of the Parrots are social and affectionate. Mr. Wilson relates some interesting traits of a species which inhabits the United States. When one of a flock is shot, they do not fly away, but remain, hovering around the unfortunate victim, and uttering cries of distress. One of them was kept in a cage, and, when this was hung in the open air, crowds of wild birds gathered around, and kept up with him a continual chattering. A second captive was introduced, to the great delight of the first. He was constantly at his side, caressed him, nestled close to him, and slept with his head under his wing. After a while one of them died. Mr. Wilson then sometimes placed a looking-glass by the side of the survivor, who, mistaking the image for his lost companion, manifested much joy, and, placing his head against the glass, went to sleep.

The Passenger Pigeon of North America is perhaps the most remarkable of birds for the immense numbers which are gathered together at the period of hatching and rearing their young. They frequent certain tracts of country, year after year in succession, and build their nests in company, upon the trees of a particular part of the forest. From these "roosting-places," as they are called, they are sometimes obliged to fly fifty or sixty miles daily to feed. Mr. Wilson gives a graphic account of one of these places of resort in the State of Kentucky. He describes it as several miles in breadth and about forty in length. The birds arrive about the tenth of April and depart in the latter part of May. As soon as they arrive, the inhabitants collect from all parts of the country and begin a deadly warfare upon them. The ground beneath the trees where they have hatched their eggs is strewn with leaves, branches, nests, and the young birds they contained. Men are employed in cutting down the trees for the sake of the squabs. As many as a hundred nests have been counted upon a single one. Droves of hogs roam through the woods, feasting upon those which escape the vigilance of the hunters. The branches and the air are filled with myriads of the parent birds, whose wings produce a roaring like thunder, only interrupted by the crash of falling trees. High above all soar numbers of kites, hawks, buzzards, and eagles, darting down from time to time to seize their unresisting prey. Every morning they started before sunrise for the Indiana Territory, a distance of sixty miles, to feed; from whence they began to return by the middle of the forenoon, and continued through the day. Mr. Wilson states, that, as he was travelling in their neighborhood, he saw them flying in one direction all the morning, and at noon beginning to return. At one o'clock, having reached a convenient spot for the purpose, he took out his watch to determine how long they would be in returning. He waited a long time in vain. They continued to pass him in an uninterrupted mass, stretching in every direction as far as the eye could reach, and so thick as to darken the heavens. At four o'clock the same regular current was passing on, and flocks of stragglers did not cease to arrive till evening. He calculates that the number of this flock could not have been less than two thousand two hundred and thirty millions.

This estimate, enormous as it is, is amply confirmed by many other observers of undoubted authority, especially by Audubon. But these numbers sink into insignificance when compared with those of many species of insects. Swarms of Gnats have been observed so large as to fill the air for miles, and to give it the appearance of being filled with smoke. The Locust prevails sometimes in such enormous numbers as to destroy the vegetation of extensive districts of country. Within a few years, the master of a vessel relates that off the Western Islands he fell in with a field of Grasshoppers, through which he sailed for five days. The water was heavily crusted with them, so that they covered its surface to the depth of some inches, during a run of some four hundred miles. They were supposed to have been blown off the coast of Africa.

The following account of a flight of Locusts is given by a recent traveller in South Africa. "We were standing in the middle of a plain of unlimited extent, and about five miles across, when I observed them advancing. On they came like a snow-storm, flying slow and steady, about a hundred yards from the ground. I stood looking at them until the air was darkened with their masses, while the plain on which we stood became densely covered with them. Far as my eye could reach, east, west, north, and south, they stretched in one unbroken cloud; and more than an hour had elapsed before their devastating legions had swept by. Locusts afford fattening and wholesome food to man, birds, and all sorts of beasts. Cows and horses, lions, jackals, hyenas, antelopes, elephants, &c., devour them. As it was difficult to obtain sufficient food for my dogs, I and Isaac took a large blanket, which we spread under a bush, whose branches were bent to the ground with the mass of locusts which covered it, and, having shaken the branches, in an instant I had more locusts than I could carry on my back; these we roasted for ourselves and our dogs. The cold, frosty night had rendered them unable to take wing till the sun had restored their powers."

'As Caterpillars do not produce their young till they arrive at the butterfly state, their associations have no respect to the rearing or education of young. Self-preservation and individual convenience are the only bonds of their union. A perfect equality reigns among them, without any distinction of sex or even of size. Each takes his share of the common labor; and the whole society, which constitutes but one family, is the genuine issue of the same mother.'

The most remarkable and perfect societies are those exhibited by the various species of wasps, bees, ants, and the termites, already described. These insects exhibit associations apparently as perfect in their organization, in their subordination of ranks, in the subdivision of labor, and in the uniform and regular combination of all the individuals for the common purposes of the community, as those of mankind. The principal circumstances which illustrate the character of these communities will be found under other heads, as "Habitations," "Hostilities," &c. The most remarkable feature to be noticed here is the nature of the government which prevails, and of the relation which the individual bears to the whole community. Among the Honey-bees, for example, there is one female around whom the society concentrates itself. She is the basis of their association and their operations. But she bears nothing of that relation which a human ruler bears to his people. She does not govern, she does not direct. She is simply the mother of the family. The great purposes of the community are the provision of food and the care and raising of the young. In carrying out these purposes, every individual appears to act without direction, mainly from his own personal impulses. The queen takes no cognizance of his labors; she exercises no superintendence. Yet, as she is a necessary agent in one of these purposes, the rest have an instinctive perception of the necessity of her presence. When she dies from any accident, disorder instantly prevails. No new cells are constructed. Neither wax nor honey is collected. There is nothing but confusion and anarchy, till a new sovereign is obtained. Everything then goes on as before.

Societies of Ants are as remarkable and interesting as those of the bees, and their arrangements are even more complicated and various. They have been, perhaps, less perfectly studied, only because they are less useful to mankind. The principal circumstances relating to them will be found detailed in other chapters. There is, however, one singular relation which some species of ants bear to other ants, and to other insects also, which is worthy of notice here.

There are many insects, inhabiting certain plants, and known under the names of *pucerons*, *aphides*, or *plant-lice*, which exude from their bodies a peculiar fluid, in small limpid drops of a sweet taste. This is a favorite food of some ants, and is not only taken up by them when it has been deposited upon the leaves, but also is directly sucked up as it is produced by the animals themselves. Huber gives the following account of his first notice of this singular phenomenon. He watched closely the movements of a single ant. "I saw it at first pass several pucerons, which it did not, however, disturb. It shortly after stationed itself near one of the smallest, and appeared to caress it, by touching the extremity of its body, alternately with its antennæ, with an extremely rapid movement. I saw, with much surprise, the fluid proceed from the body of the puceron, and the ant take it in its mouth. Its antennæ were afterward directed to a much larger puceron than the first, which, on being caressed after the same manner, discharged the nourishing fluid in greater quantity, which the ant immediately swallowed." This process it repeated on a succession of individuals, till its appetite was satisfied, when it returned perfectly contented to its nest. Huber observed the same relation to exist between ants and the gall insect; and, so far from this supply of food being regarded as plunder, these insects and the ants live together on terms of the most perfect amity. Farther than this, societies have been observed in which the pucerons live together in the same community with the ants, feeding themselves from the roots of plants, and furnishing their fellow inhabitants with the secretion they so much prize, and which, in some communities, constitutes their principal food.

These pucerons, therefore, stand in the same relation to ants, that cows and goats do to the human race. The ants take care of them, guard them from being stolen by other ants, in times of danger convey them to a place of safety, and, in fact, regard them with the same jealous care that a man does his flocks and herds. They go even farther than this. They collect their eggs, transfer them to their own nests, take the same precautions with regard to them that they do with regard to their own, and, when the new animal has come to life, rear it with assiduous care and add it to their stock.

A still more remarkable circumstance has been observed with regard to a species of ants, called, on account of their martial character, Amazons. These sometimes constitute a community by themselves, all its offices being performed by individuals of the race. But in other cases they attack in large numbers the nests of another species, of a dark ash-color, drive away their inhabitants, seize upon their larvæ and pupæ, and convey them to their own residences. Here these are hatched and reared, become the property of their captors, and are the sole laborers of the community. They build the nests, they procure food, they even take all the charge of the larvæ, which are from time to time brought in by the Amazons after their hostile excursions. They are, in fact, reduced to the condition of slaves; and from their dark color, as compared with those whom they serve, have been called *negroes*. In fact, the Amazon bears to them the same relation, both in condition and color, that the white man does to the black man whom he enslaves. There is this difference: — the Amazons replenish their own numbers in the ordinary way, there being among them, males, females, and neuters; but the negroes do not breed in captivity; only the neuters, or laborers, are made captive, and their number is only kept good by a perpetual robbery.

Though thus systematic in their policy, it does not appear that the affairs of a community of ants are carried on under the direction of any chief. They march forth in bands, but it is like a horde of undisciplined barbarians, and not like regular troops, organized, and guided by their leaders. Each individual acts in concert with the others, but it is under the mysterious direction of his own impulse, and not at the command of an acknowledged master. They constitute a most absolute democracy, in which there is not even a temporary government to which they acknowledge submission, but where the instinctive subservience of each individual to the purposes of the community takes the place of laws that depend for their execution upon subordination of ranks.

CHAPTER XV. (W.)

OF THE HOSTILITIES OF ANIMALS, AND THE DESTRUCTION OF ANIMAL LIFE.

DEATH is an established law of Nature, and is as necessary an event in the order of Nature and Providence as birth. Every animal sooner or later comes to the termination of its existence, as the result of an inevitable law of Life. Very few, however, even of our own species, who have it in their power to study out and put in practice the best means for the prolongation of life, reach its natural term. A large proportion of mankind, by violence, want, accident, or disease, are prematurely cut off; and of other species a still larger proportion are sacrificed to the same causes, and more especially to that provision by which one animal becomes the food of another.

Man is the most universal destroyer. His empire over animals, by means of his intellect, his skill, his ingenuity, and his artifices, is unbounded. He subdues them to his uses as domestic slaves, and then slaughters them as food. He hunts them in the wild state for their skins, their hair, their fur, their teeth, their horns, and their flesh. He pursues and destroys them for his amusement. He lays each kingdom under contribution for his wants, his comforts, his love of gain, or his pastime.

Next to him come the carnivorous quadrupeds, some of whom, live exclusively on flesh, whilst others are addicted to a mixed diet, and can even subsist upon vegetable productions alone. By their depredations, immense numbers of lives among the smaller tribes are daily destroyed, though the larger species, as the elephant and the buffalo, by no means escape their ravages. Among birds, the carnivorous propensity is far more universally diffused. Of the exclusively carnivorous, the number is not very large, neither is it so of the exclusively herbivorous. There are few species to whom worms, insects, and indeed animal food in many forms, does not prove a welcome repast.

But the amount of destruction among terrestrial animals is small as compared with that which takes place among the inhabitants of the ocean. With few exceptions, these are all carnivorous. The whale opens his capacious jaws, and at a single swallow engulfs millions of the smaller animals of which the waters are full. The larger fish are constantly in pursuit of the smaller; while the smaller devour the spawn of the larger, as well as worms, mollusca, and zoöphytes. Their whole life seems to be spent in the search for food; and so eager is their appetite, that scarcely anything is rejected. With few exceptions, they seem to be devoid of the parental instinct, and devour their own offspring as readily as anything else.

The demand for air is so urgent, and the want of it so immediately destructive of life, that its supply has not been made dependent upon the voluntary efforts of the individual. It is not only universally diffused over the surface of the earth, but penetrates its interior, and pervades the waters also. It is not so with food, the deprivation of which is as certainly, though less immediately, fatal. Animals are led to seek for it by an appetite of the most imperious and irresistible nature; and, as the necessity for it is constantly returning, the desire for it is so constantly present, that, when not asleep or interested by the sentiments and occupations connected with the production and care of their young, their attention appears to be mainly engaged, and their lives to be spent, in seeking and enjoying a supply of food. The desire of satisfying this one appetite seems to be the ever-predominant feeling in every animal, so far as it is a conscious being; and even in those lower tribes, where the functions of life are carried on either without any distinct consciousness or with a very feeble degree of it, the same propensity governs the economy, even though it be not felt, or be not connected with a clear effort of the will.

The necessity for a regular supply of food is, therefore, one of the principal causes of the destruction of life, and hunger the most urgent of the appetites. It leads animals to brave every danger. When excessive, it even overpowers the love of offspring; inducing the parents to sacrifice the necessities of their progeny to their own, and even to devour it. Those which usually stand in awe of man, will then venture to attack him. The wolf becomes almost frantic under the pangs of hunger. All idea of fear is banished. He attacks companies of armed men; he assails human dwellings. He is repelled only by the most determined resistance, and by a wholesale slaughter. He returns again and again to the assault. The eagle, in his ordinary condition, is afraid of man, and is easily driven away even by children; but, when impelled by excessive hunger, he not only seizes kids, lambs, goats, and the young of the reindeer, but has been known to attack the young of our own species. There is a tradition among the Swiss of a most painful occurrence connected with the lammergeyer, or great eagle of the Alps. A young mother, whilst engaged at work in the fields, laid her child down upon the ground, at a short distance from her. It was sleeping quietly, when it was suddenly pounced upon by a large eagle, and borne away in its talons. In vain the poor mother pursued with frantic cries. In vain she implored aid from others. For a considerable time the screams of the helpless infant were heard through the air. They gradually became fainter and fainter in the distance, and the wretched mother saw her child no more. She became a maniac.

Two little children, of five and seven years of age, were amusing themselves together in a wheat-field, in imitation of the reapers, when a large eagle came down upon them and attempted to seize the elder. The boy, being armed with a sickle, repelled the attack. The bird, though foiled, was not daunted, and, alighting at a short distance, soon repeated the assault. The courageous boy struck at him resolutely with his weapon, which, fortunately, entered under the wing, passed through the ribs, and, wounding a vital part, laid his enemy dead at his feet.

Beside the immense destruction of the life of animals which is the result of this consumption of them as food, vast numbers fall a sacrifice to other causes. Fishes, when assembled in large shoals near the land and in shallow waters, are driven on shore by the force of the winds and waves, or are crowded out of their element by the mere pressure of excess of numbers. Among the immense herds of American buffaloes, many are trodden under foot and destroyed, many are crowded down the banks of rivers, or from precipices. Thousands of squirrels are drowned in attempting to swim across rivers at an unfavorable moment. Myriads of birds fall a sacrifice to severe and untimely storms. Crows have been supposed to be destroyed in large numbers by lightning, and in Ireland thirty-three thousand of these birds were found dead, in 1839, on the shores of a lake, in the county of Westmeath, after a violent storm. Locusts, in numbers so great the imagination even cannot embrace them, are blown into the sea, and perish by drowning, or for want of food. Smaller insects, that fill the air for miles in extent, perish in a single night, at the natural term of their existence, or by some unknown and untimely cause of destruction.

When we contemplate such an unstinted destruction, we almost imagine that, as its consequence, whole species must be sometimes struck out of existence; but on the other hand, such is their fecundity, we find that we are equally at a loss to know how the due balance of numbers is preserved, where the production is so great and the number of individuals so much beyond our power to calculate. Several statements have been before made as to insects, fishes, birds, and even quadrupeds; and, in addition to these, Captain Hamilton gives an account, equally remarkable, of the myriads of some of the herbivorous quadrupeds of South Africa:—"I was awoke from my sleep on the ground, by a noise as of distant thunder. On looking up, I saw the plain covered with dust, as if an army were engaged; and presently the dark columns of countless thousands of wildebok, springbok, blessbok, and other animals, charged along the plain within shot. They were in a dense mass of great breadth, and apparently extending to the horizon."

The reproductive powers of fishes are so great that, notwithstanding the immense numbers which are taken as food for man and consumed by other inhabitants of the sea, there is no diminution in their numbers.* The Bay of Naples has furnished a supply for a dense population upon its shores ever since the memory of man; and the cod, herring, and mackerel fishery, in various parts of the world, have produced no apparent impression upon the immense shoals that visit certain shores. About one hundred thousand persons are engaged in the Scottish herring fisheries, and the total produce for a year amounts to about a million of barrels. The depredations of man, however, are as nothing compared with those of the carnivorous inhabitants of the ocean. But though this is true of the smaller fishes, it is not so of the larger animals of the ocean. In those seas where whales have been hunted for their oil, their numbers, and the age and size of those taken, have diminished so sensibly that it has been necessary to explore new fields. In rivers and lakes of limited extent which are much resorted to, even the smaller fishes are sometimes nearly exterminated.

The chief actuating motive, in the examples already given of the destructive propensity, is the appetite for food. These, however, by no means include all the cases of the extensive destruction of the life of animals by the agency of other animals. The motive for this we can, in some cases, detect; in others, not. In many, there is an independent love of contest for its own sake; a disposition to fight, which seems to have no other object than the excitement that attends it, and the gratification of certain passions, whose indulgence, in some natures, is attended with a strange species of satisfaction. Such is eminently the case with man, when under the dominion of his mere animal nature. In his state of barbarism, war, which then consisted almost entirely in personal conflict, was his chief employment, from which he derived his highest enjoyment, and which he regarded as the source of his greatest glory. The associations long connected with it, by a strange inconsistency he has continued to cherish, even after becoming educated, civilized, and refined; and he does not yet perceive how much the passions it implies, and the means it requires, are at variance with the moral and religious principles

* A cod, according to Leuwenhoek, produces nine millions of eggs in a single season, and other fishes a very large number.

he reverences. From the same propensity arises the interest taken in encounters of a cruel and revolting character, both among men and animals, — cock-fighting, bull-baiting, gladiatorial shows, pugilistic encounters, and duels. It is curious to observe the influence of habit in preventing a perception of the real character of this interest. The brutal sport of our own nation we regard as noble and manly, whilst that of another we readily see in its true light. The American and Englishman sympathize with men who meet to bruise one another with their fists, sometimes to the destruction of life, as champions of "the noble art of self-defence," but look with horror on bull-baiting, or bear-baiting, as a barbarous and cruel amusement, and upon the gladiatorial contests of the ancients, as the result of their low state of civilization. Yet it would be difficult, upon the principles of an enlightened morality, to point out any essential difference between them.

Among animals are found many that display a similar propensity, especially the dog and the cock of the domestic species, and various animals of the wild; but the most striking examples are found among insects, and will be more particularly described hereafter.

A disposition to destroy life wherever it is found, is also observed among some men and many animals, independently of any purpose to be answered, or any use to be made of the victims. We find this in the dog,* the cock, the weasel, &c.; but in none is it more obvious than in certain individuals of our own species.

* Dogs have been known to destroy vast numbers of sheep without apparently devouring any part of them, the only mark of injury being a bite in the throat. In other cases, they merely gratify the taste for blood by sucking a small portion, or confine themselves to a few mouthfuls of some delicate part. A dog was left by some smugglers on the coast of Northumberland, and began, in his state of destitution, to destroy sheep in great numbers, eating only the fat about the kidneys, so that numbers were required for his sustenance. His ravages at length rendered him the scourge of the district, and he was hunted a long time without success. When overtaken by the hounds, he threw himself on his back, as if supplicating for mercy. In this position they never touched him, and on the approach of the hunters he would get up and make off, the hounds not following till they were again excited by their masters. His constant residence was upon the top of a rock, where he had a view of four roads leading to it. Here, after a career of bloodshed for a year, he was at last killed.

There is something revolting to the moral sense in the pleasure taken by many persons in the mere slaughter of animals, and those not of a noxious or offensive kind, for its own sake, under the pretence that it is a noble and manly exercise. Of this kind is the hunting of the timid with hounds and horses, which has not even the recommendation of adventure and danger to give it a manly character. Of the same nature, though less effeminate as a matter of taste, are the expeditions of men professing refinement and civilization, to remote districts of the earth, for the sole object of destroying the nobler beasts of the desert, and with no distinct purpose except to gratify the love of destruction. It is an amusement which, when followed solely as such, is a relic of barbarous ages, still adhering to modern civilization. The destruction of animal life for the sake of food and clothing, or for the removal of races that are offensive and injurious, is perfectly justifiable; but not so their destruction as a mere sport. Children are taught that the killing of flies, and the tormenting of small animals, are cruel sports. It is difficult to show in what these differ from the sport of hunting by grown men, as to the purpose or the sentiment with which it is followed. The trade of a butcher is looked on as a harsh and cruel one; but it is attended with less suffering to its victims than is felt by those who are made the subjects of the fear and terror incident to a long chase, and the protracted agonies of gunshot wounds, which are often only sufficient to maim, not to destroy.

It should humble somewhat the pride of man to reflect, that he is most closely imitated in this unamiable propensity by races of insects, possessed of little voluntary intelligence, but mainly governed by a blind, undiscriminating instinct. The communities of bees and ants furnish the most remarkable examples of this tendency to warfare and destruction, sometimes with and sometimes without any other object than the love of combat, the desire for victory, and the pride of success.

In some cases there is undoubtedly a purpose in the economy of Nature which is answered by this destructive disposition, though we may not be always able to understand what it is. Of this sort is the war of extermination which is waged by the first queen bee hatched in a hive upon all those which subsequently come into existence. These she attacks with the most furious animosity, and either kills, or is killed by, her antagonists. She also seeks to destroy the immature queens which have not yet left the cell. This massacre is necessary in order that only a single queen may be left for each swarm; but though this be the ultimate purpose, the contest is carried on with all the appearance of anger and animosity that only an actual hatred can inspire. Of the same character are the massacre of the males, or drones, which takes place at that season of the year when they have ceased to be useful members of the community, and the destruction by wasps of large numbers of their offspring toward the approach of winter.

But furious combats take place among bees, for which no sufficient motive can be imagined. These sometimes occur between different swarms, and sometimes between parties in the same swarm. The contest takes place in the air, which is filled with the combatants; and yet, however universal the warfare among the inhabitants of a hive, the actual conflicts are always single, and the individuals engaged exhibit indications of the greatest fury and the most ferocious and vindictive passion.

Communities of ants, however, afford the most wonderful instances of war on a large scale, carried on in the most systematic manner, and giving occasion to the most frightful slaughter. The following narrative describes a remarkable example of this sort.

"In the year 1845 the shop of a watchmaker in Boston was infested with the common red ants. They did not appear to inhabit or frequent any particular spot, but were found in the tool-drawers, on the benches, and about the walls. As, from the nature of the place, food was scarce, they appeared to act in the capacity of scavengers, and lived upon such flies as died on the windows, &c. If a fly were killed, and placed upon a work-bench, in less than a minute the body would be surrounded by dozens of ants, who would in an incredibly short space of time carry the whole carcass away. Beyond a few experiments with dead flies, no attention was paid to them by the occupants of the shop, and no attempt made to destroy them, or to reduce their numbers. For a year or eighteen months they continued to infest the premises, attracting no special notice, except to the somewhat curious fact that they continued to frequent so sterile a place at all.

"One morning they were observed to be in a state of unwonted agitation; a violent struggle appeared to be in progress among the usually peaceful community. The bench at which the writer of this article sat was covered with groups and detached pairs of ants apparently engaged in deadly combat. It being supposed that a hostile colony had made a descent upon the old residents, and that they had taken the work-bench for a battle-field, search was made in the drawers and cupboards which they were known to frequent, partly to ascertain if there were any difference between the fighting ants and those left behind, and partly, if it were possible, to tell the proportion of combatants to non-combatants. But, to the writer's astonishment, wherever they were found, in drawer, closet, or cupboard, they were fighting; the strictest search could not discover a single stray ant; every one was engaged in the conflict.

"From a desire to observe the result of so singular a combat, a number of groups and pairs of struggling ants were placed upon a sheet of white paper, and a strong magnifying glass was brought to bear upon them. It was then seen, that each ant was grappled by his antagonist round the body by means of the four hind legs, and so firmly that no force short of tearing their bodies to pieces could part them. The two fore legs, or arms, were used like, and very much resembled, those of wrestlers in a wrestling-match. Each individual seemed to try to fasten his fangs upon the other's shoulder or neck, and at the same time to prevent, with his arms, his antagonist from doing the same to him. If by superior strength or skill he succeeded in this, his hold was not relinquished until he had severed the head or the arm from the body. But when thus successful, the victor could not disengage himself from his antagonist, and, after fruitless struggles, died in the embrace of his victim.

"Some appeared to be well and equally matched. Placing their arms against each other's heads to ward off the death-grip, they would remain for hours without gaining any apparent advantage, till one would succumb from fatigue or lack of skill, and the other's fangs would do their work.

"The contest continued for more than twenty-four hours, when, every combatant appearing to be dead, they were collected from the benches and drawers to the amount of nearly a gill by measurement. A live ant has never been seen in the shop since.

"For years afterwards it was not unusual, in removing papers, &c. in neglected corners, to find dead ants, but always clenched together as in their last struggle." *

In this contest no definite purpose is discoverable. So far as it can be understood, it seems to have been merely an exhibition of the pugnacious propensity on the part of those engaged, in this respect resembling too many of the wars waged by our own race. There is not even any evidence that it occurred between the members of two distinct societies, though probably this might have been the case. In other instances, according to the observations of Huber, battles take place between large communities, inhabiting distinct residences, sometimes of the same and sometimes of different species. The weapons used are chiefly the arms and mandibles, but some species employ in addition a sting with which they are armed. They are capable also of emitting a poisonous liquid, and this they pour upon each other. For the most part they fight in pairs, as described in the preceding account, but occasionally a third comes to the aid of his fellow-countryman, and sometimes several are concerned in a common struggle.

The following account, given by Huber, furnishes a specimen of these remarkable contests. "If we wish to behold regular armies, war in all its forms, we must visit those forests in which the fallow ants establish their dominion over every insect in their territory. We shall there see populous and rival cities; regular roads passing from the ant-hill as so many rays from a centre, and frequented by an immense number of inhabitants; and wars between hordes of the same species, for they are naturally enemies and jealous of the territory which borders their own capital. It is in these forests I have witnessed the inhabitants of two large ant-hills engaged in spirited combats. I cannot pretend to say what occasioned discord between these republics.

* This remarkable account was furnished by Mr. Z. A. Willard, of Boston, upon whose good faith, and accuracy of observation and description, entire reliance may be placed.

They were composed of ants of the same species, were alike in their extent and population, and were situated about a hundred paces distant from each other. Two empires could not possess a greater number of combatants.

"Let us figure to ourselves this prodigious crowd of insects, covering the ground lying between the two ant-hills, and occupying a space of two feet in breadth. The two armies met halfway from their respective habitations, and then the battle commenced. Thousands of ants took their station upon the highest ground and there fought in pairs, keeping firm hold of their antagonists with their mandibles. A considerable number were engaged in the attack and in leading away prisoners. The latter made several ineffectual efforts to escape, as if aware that upon their arrival at the camp they would experience a cruel death. The scene of warfare occupied a space about three feet square; a penetrating odor exhaled from all sides; numbers of dead ants were seen covered with venom. Those ants that composed groups and chains took hold of each other's legs and pincers, and dragged their antagonists on the ground. These groups formed successively. The fight usually commenced between two ants, who seized each other with their mandibles, and raised themselves upon their hind legs, to allow of their bringing the abdomen forward, and spirting venom upon their adversary. They were frequently so closely wedged together that they fell upon their sides, and fought a long time in that situation, in the dust; they afterward raised themselves, when each began dragging its adversary; but when their forces were equal, the wrestlers remained immovable, and fixed each other to the ground, until a third came to decide the contest. It more commonly happened that both received assistance at the same time, when the whole four, keeping firm hold of a foot or antenna, made ineffectual attempts to gain the battle. Other ants joined them, and these were in their turn seized by new comers. It was in this way they formed chains of six, eight or ten ants, all firmly locked together; the equilibrium being broken only when several warriors from the same republic advanced at the same time, who compelled those that were enchained to let go their hold, when the single combats again took place. On the approach of night, each party returned gradually to the city which served for an asylum. The ants which were either killed or led away into captivity not being replaced by others, the number of combatants diminished, until their forces were exhausted.

"The ants returned to the field of battle before dawn. The groups again formed; the carnage recommenced with greater fury than on the preceding evening, and the scene of combat occupied a space of six feet in length by two in breadth. Success was for a long time doubtful; about mid-day the contending armies had removed about the distance of a dozen feet from one of their cities, whence I concluded some ground had been gained.

"The common operations of the two colonies were not suspended during this warfare; the paths which led to a distance in the forest were as much thronged as in a time of peace, and all around the ant-hill order and tranquillity prevailed, with the exception only of that side on which the battle was raging. A crowd of insects was constantly seen to be setting off for the scene of combat, while others were returning with their prisoners. This war terminated without any disastrous results to the two republics; long continued rains shortened its duration, and our warriors ceased to frequent the road which led to the camp of the enemy.

"It is a remarkable circumstance that the combatants are able always to distinguish those which are of their own party. How and by what sign do they distinguish their compatriots, in a contest in which thousands of individuals of the same color, of the same size, of the same odor, and of the same species, meet, attack, or defend themselves, inundate their adversaries with venom, and lead away prisoners? They sometimes attack those of their own party; but on recognizing them immediately relax their hold. It often happens that those who are the objects of this temporary error caress their compatriots, and readily appease their anger."

A still more striking illustration of this power of recognizing the inhabitants of the same community is related by the same author. "I took," says he, "in the month of April, an ant-hill from the woods, for the purpose of peopling my large glazed apparatus; but, having more ants than I had occasion for, I gave liberty to a considerable number in the garden of the house where I lived. The latter fixed their abode at the foot of a chestnut tree. The former became the subject of some private observations. I noticed them four months, without allowing them to quit my study; at this time, wishing to bring them nearer to a state of nature, I carried the *ruche* [apparatus] into the garden, and placed it at ten or fifteen paces from the natural ant-hill. Some of the prisoners, profiting by my negligence in not renewing the water which blockaded their passage, escaped, and ran about the environs of their abode. The ants established near the chestnut tree met and *recognized* their former companions, fell to mutual caresses with their antennæ, took them up with their mandibles, and led them to their own nests; they came presently in a crowd to seek the fugitives, under and about the artificial ant-hill, and even ventured to reach the bell-glass, where they effected a complete desertion, by carrying away successively all the ants they found there. In a few days the *ruche* was depopulated. These ants had remained four months without any communication."

Wars also take place of a still more singular character between certain species, the investigation of which has brought to light some very curious relations between them, of which a general account has been given in the preceding chapter. The rufescent ants, or as they are called by Huber, Amazons, employ those of another kind, the ash-colored or Negro ants, as servants or slaves. They live together in the same community, the Amazons acting as soldiers and performing other offices abroad, the negroes remaining at home employed in the internal duties of the establishment. The negroes, however, are not enslaved in their fully developed condition. In this state it is probable they could never be domesticated. They are seized by the Amazons in the state of larvæ, are conveyed to their habitations, and there undergo their final metamorphosis. None but neuters are thus appropriated. They do not breed in the state of servitude, but their numbers are kept good by perpetual expeditions of their masters, in which the communities of ash-colored ants are robbed.

A full account is given by Huber of a number of these predatory excursions. His first observation of them is described in the following words. "On the 17th of June, 1804, whilst walking in the environs of Geneva, between four and five in the evening, I observed close at my feet, traversing the road, a legion of rufescent ants. They moved in a body with considerable rapidity, and occupied a space of from eight to ten inches in length by three or four in breadth. In a few minutes they quitted the road, passed a thick hedge, and entered a pasture ground where I followed them. They wound along the grass without straggling, and their column remained unbroken, notwithstanding the obstacles they had to surmount; at length they approached a nest, inhabited by ash-colored ants, the dome of which rose above the grass at a distance of twenty feet from the hedge. Some of its inhabitants were guarding the entrance; but, on the discovery of an approaching army, they darted forth upon the advanced guard. The alarm spread at the same moment in the interior, and their companions came forth in numbers from their underground residence. The rufescent ants, the bulk of whose army lay only at the distance of two paces, quickened their march to arrive at the foot of the ant-hill; the whole battalion, in an instant, fell upon and overthrew the ash-colored ants, or negroes, who after a short but obstinate conflict retired to the bottom of their nest. The rufescent ants now ascended the hillock, collected in crowds on the summit, and took possession of the principal avenues, leaving some of their companions to work an opening in the side of the ant-hill with their teeth. Success crowned their enterprise, and by the newly-made breach the remainder of the army entered. Their sojourn, however, was of short duration, for in three or four minutes they returned by the same aperture which gave them entrance, each bearing off in its mouth a larva or pupa; they retraced the route by which they had arrived, and proceeded one after another, without order or regularity. The whole army might be readily distinguished in the grass, by the contrast afforded by the rufescent ants and the white eggs and pupæ they had captured."

There is another species, the Mining ants, that are made captives and enslaved in the same way by the rufescent ants or Amazons. But those are a more courageous and spirited race than the ash-colored, and offer a more determined resistance. In carrying off their booty from the negroes, as in the above instance, the army observes no order, but separates into straggling parties, each hastening by the easiest route to deposit their spoil in their common depository. When, however, they return successful from an attack upon a nest of the mining ants, they proceed with greater caution, keep close order, and march in a body to the very gates of their citadel; and it not unfrequently happens that they are followed and harassed the whole way by those they have robbed, who make strenuous exertions to recover their lost treasure.

On their return home after these excursions, they are met by the negroes, who have been left alone in charge of the nest. These caress them, furnish them with food, and relieve them of the larvæ, which they convey away into a suitable place, where they afterwards take the entire charge of them. The Amazons subsequently take no notice of them whatever, never deigning even to lift them, or, indeed, to bear any part in the labors going forward in the interior of their citadel.

By another species, the Sanguine ants, similar enterprises are undertaken, but conducted in a somewhat different manner. They attack the habitations of the same kinds of ants as the former, that is, the negroes and the miners. Huber gives the following account of one of these expeditions. "At ten in a morning in July, I observed a small body sally forth from their formicary, and march rapidly to a neighboring residence of negro ants, around which they dispersed themselves. The inhabitants rushed out in crowds, attacked them, and took several prisoners; the remainder paused, but, being soon reinforced by new arrivals, advanced nearer the besieged city, and at length assembled in great numbers before it. The negroes, coming out of their habitations, formed themselves into a body about two feet square, in front of them. The general conflict was preceded by several skirmishes. At last the actual battle was begun by the negroes; but, before success appeared to incline to either party, the pupæ — the object of the incursion — were carried off, and heaped up on the side of the nest opposite to that where the attack was made. The young females also fled to the same quarter. At last by a vigorous assault the negroes are defeated, but still strive to preserve the objects of their care; this, however, is prevented, and the assailants carry off the young brood to their own nest. A continued chain of ants employed in this work extends from one city to the other till the whole is completed. Sometimes the conquerors, leaving their own habitation, take possession of that from which they have driven the rightful possessors."

The captives thus made become part of the community into which they have been introduced. They are exposed to no oppression or hardship or ill treatment. Their condition is probably very much the same that it would have been in their native abode. They are employed in various laborious occupations,—in making necessay repairs of the common habitation, in collecting food, in attending and feeding the females, and in performing various offices for the security and regular development of the eggs, larvæ, and pupæ. They also feed and carry about their masters, who take no part in any laborious employment, but, though so enterprising and active in predatory excursions, are at other times entirely devoid of industry and energy, and depend upon these slaves for food, and for motion from place to place. They are, indeed, in all the ordinary economy of life, the subjects rather than the rulers; and, singular as it may seem, when left entirely to themselves and deprived of the services of their slaves, they have been known to perish from absolute want.

This account is, however, only strictly true of the rufescent ants; the sanguine, though availing themselves of the same services from the subordinate species, are less indolent and helpless, and take some interest in the responsibilities and labors of the settlement. In some instances this is even the case with the rufescent, especially at the first foundation of a new society. The influence of circumstances and of education in modifying the instinctive tendencies of these animals is shown by the curious fact mentioned by Huber, that the pupæ of both these species being placed together by him in an artificial formicary, under the charge of a number of negroes, arrived at the perfect state together, and lived in the same habitation in perfect amity.

There are some other curious circumstances in the economy of these wonderful animals, which, although not strictly falling within the subject of this chapter, are yet so well calculated to illustrate the same general points of character, that they will be best introduced here. The following narrative of Huber relates to the species denominated the Fallow ants, and details, not a battle between them, but a contest apparently friendly, and of the same nature as the various games and sports among mankind, and also among the young of many animals. "I visited, one day, one of their ant-hills, exposed to the sun and sheltered from the north; the ants were heaped upon one another in great numbers, and appeared to enjoy the temperature upon the surface of the nest. None of them were at work. This immense multitude of insects presented the appearance of a liquid in the state of ebullition, upon which the eye had some difficulty in resting; but when I examined the conduct of each ant, I saw them approach each other, moving their antennæ with astonishing rapidity. With slight movements of their fore feet they patted the lateral part of the head of the other ants. After these first gestures, which resembled caresses, they were observed to raise themselves on their hind legs by pairs, struggle together, seize each other by a mandible, foot, or antenna, and then immediately relax their hold to recommence the attack. They fastened on the thorax or abdomen, embraced and overthrew each other, then raised themselves by turns, taking their revenge without doing any mischief. They did not spirt forth their venom, as in their combats, nor retain their adversary with that obstinacy which we observe in their serious quarrels. They presently abandoned the ants they had seized, and endeavored to lay hold of others. I saw some who were so eager in these exercises, that they pursued successively several workers, and struggled with them a few moments, the combat only terminating when the least animated, having overthrown his antagonist, succeeded in escaping and hiding in one of the galleries. I frequently visited this ant-hill, which almost always presented me the same spectacle, but I never saw any quit it wounded or maimed."

According to Dr. Livingston, there is in South Africa a species of red ant, which exists in great numbers and is remarkable for its ferocity. They are frequently met with in numbers like a small army. At a little distance they appear as a brownish red band, two or three inches wide, stretched across the path, all eagerly pressing in one direction. If a person treads upon them they rush up his legs in great numbers, and seem almost at once to attack every part of his person, biting with great fury, and their bites being like sparks of fire. They not only bite, but twist themselves round after the mandibles are inserted, so as to increase the torture, and their unfortunate victim becomes almost beside himself with anguish. They have no fear, attacking with equal ferocity the largest as well as the smallest animals. When any person has leaped over them, numbers rush from the ranks, seeming anxious for a fight. They are especially fond of flesh, and are of service in destroying the carcasses of animals, and in clearing any human habitations they may visit of the white ants and other vermin. Even living animals are not always safe from their destructive propensity.

CHAPTER XVI. (W.)

DURATION OF LIFE.

As the life of every organized being begins by conception and birth, so it ends by death and decay. There is no escape from this universal law. If the beginning of life, if the introduction of a new being is mysterious, the end of life, the destruction of this being, is equally so. We can conceive neither how a new agency should come into creation, nor how it should go out.

The whole of the existence of an organized being is a series of changes. It is not at any two consecutive periods precisely the same. This is not only true of the materials of which it is composed, it is also true of the law by which its organization is maintained. Though this law has always essentially a uniform character and tendencies, its force, and its relation to the economy that it governs, are constantly varying. Yet we can see no connection between the successive steps of this changing existence. No one of them seems necessarily to lead to that which follows. There is nothing in the caterpillar to foretell the butterfly, nothing in the egg to foretell the chick, nothing in the infant to foretell the man. There is nothing in the full-grown man that would lead us to anticipate death and decay. Experience has taught us the inevitable fact; we have learned habitually to associate the steps of the process together; it has become familiar as a necessary truth, till, like all mysteries that are familiar, it seems to have become intelligible.

When, apart from the associations of experience, we think of a human body in the full activity of its functions, and supplied with all that is necessary to their performance, we can see no reason why it should not exist and act for ever. It is often deemed sufficient to say that the body, like a machine, wears out by long use; that, though repaired after a fashion, the repair is imperfect, and that in the lapse of time it must necessarily give out. But, except in the way of a very limited illustration of some of the conditions of life, we are not machines. We are not governed, nor repaired, like machines; we do not come to an end like them. The comparison is a convenient one, if its application be limited to those points only which it really illustrates. We speak familiarly of the wear and tear of the system, as of the wear and tear of a machine; and as a figure of speech this is allowable, and is suggestive. But there is no real resemblance between the processes in the two cases; and we deceive ourselves when we are led to conceive of things as similar in all their conditions, and reason from one to the other, when in fact they are only similar in a single particular. If indeed every part of a machine were repaired as fast as it gives way, if its parts were renewed when they become imperfect, if it were moved by a power which is the result of its own activity, its similarity to a living body would be more complete, and we can see no reason why either should cease to exist and to move.

If then, we examine a living body at any one moment of its existence, or even watch it through a considerable period, we cannot conceive why time or use should destroy it; why it may not, like a rock or a crystal, endure indefinitely, so far as any element of destruction exists within itself. Of violent or accidental destruction from external causes we can conceive, as of the disintegration of a rock, or the solution of a crystal; but, in these cases, we know that no power proper to the existence of the object has been destroyed; whereas of natural dissolution, involving the extinction of the power which has kept up the organization, we can form no definite idea.

Explanations like the following are often given of the effects of time, and of the consequent natural termination of existence by death. 'When we advance in years, the bones harden, the muscles become stiff, the cartilages are converted into bones, the membranes into cartilages, the stomach and bowels lose their tone, and the whole fabric, instead of being soft, flexible, and obedient to the inclinations, or even the commands of the mind, becomes rigid, inactive, and feeble. These are the general progressive causes of death, and they are common to all animals.' 'Beside accidental diseases, which are more frequent as well as more dangerous in the latter period of life, old men are subjected to natural infirmities that originate solely from a decay of the different parts of the body. The muscles lose their tone, the head shakes, the hands tremble, the limbs totter, the sensibility of the nerves becomes blunted, the cavities of the vessels contract, the secretory organs are obstructed, the blood, the lymph, and other fluids extravasate, and produce all those symptoms which are commonly ascribed to a vitiation of the humors.' It is hardly necessary to say that these are only statements of the phenomena which attend age and death, and, in no sense, of their cause. They no more afford an explanation of the condition of age, than the opposite state of the organization affords one of the condition of infancy. In each stage of life these phenomena are consequences, not causes. Why this gradual change of organization between infancy and age? Why these progressive changes according to a law, which, if it were like other known laws of Nature, should be uniform in its operation, and consequently uniform in its results? Instead of a power which is constant and equal in its action, we here have one which is constant only in its inequality.

The theory which, so far as it goes, best explains the phenomena to which we allude, as well as all others relating to life, conceives of Life as a power lying within common or inorganic matter, and essentially distinct from those powers that govern it when life is not in it, but using that matter as material out of which to construct the forms in which life itself resides. It regards Individual Life as the cause of organization, and not as its result. If, on the other hand, organization be only the effect of a peculiar arrangement of matter, brought about by a new relation of its ordinary powers, of which the individual life is the result, we encounter at once a departure from all the laws according to which those powers have been uniformly known to operate. Their essential characteristics have been constancy and equality. If organization be the work of common matter alone, it should follow the laws of common matter, and be constant and equal. This statement undoubtedly opens into the great question which has divided the opinions of philosophers ever since the birth of human thought, — that of the separate natures of soul and body; for all arguments which apply to life as a cause or as a result, apply with the same force to mind. The discussion of this question would be out of place here; and it is merely mentioned on account of its connection with the explanation of the changing phenomena of organic, as contrasted with the unchanging phenomena of inorganic matter.

We can only conceive, therefore, of individual life as a power, in each case, definite in character, limited in amount, operating for a certain time, producing its results in a certain order, gradually exhausted by its own operation, and then, by a law of its own nature, ceasing to operate. Life does not cease because the organism in which it resides ceases to be fit for its tenancy; the organism becomes unfit because Life has ceased to be able to maintain it. This point may be safely illustrated by the analogy of a machine. Life is not a perennial stream from a perennial fountain, but a current flowing from a reservoir of definite capacity. Its force is greatest at first, and diminishes as it becomes exhausted. It turns a machine that repairs itself, but whose power of repair and action depends upon the force of the current; whilst the rapidity with which the reservoir is exhausted depends upon the amount of power which is required to support the degree of activity with which the machine is worked. The motion is maintained by a constantly diminishing force till the supply is exhausted, and then it ceases with the cessation of its cause. But, before this takes place, the machinery may be rendered incapable of performing its task by violence or imperfect repair.

This illustration does not prove, but explains, the most probable theory of the progressive changes and limited duration of life. Life is most vigorous in infancy, — for the frailness of the tenure of infant life is explicable by distinct causes, — and becomes regularly less and less vigorous as time goes on. It is exhausted with different degrees of rapidity according to various circumstances. The body undergoes a succession of changes in its organization, and gradually becomes less and less fit for the due performance of its functions, and ceases to exist, either prematurely from this cause, or at last by the entire exhaustion of the powers with which its existence began. It is seldom that life is prolonged to its utmost possible term. External influences and modes of life are constantly interfering to impair the integrity of our organs; and few men live so long as their actual amount of vitality would have enabled them. In such premature death, there is usually found some such change in the structure as is incompatible with the continuance of its functions. But in those who die in extreme old age, when life goes out like an expiring candle, without disease, there is no such change of organization merely, as renders death inevitable. The fountain is exhausted, the spring has uncoiled, the weight has run down, and a cause, which before would have hardly impeded the movements of the machine, now arrests them.

But, whatever be the truth upon these speculative points, the duration of life, as a matter of fact, is always a subject of interest; and mankind are anxious to have it determined, not only how long it is possible for them to live, but what are the circumstances which promote longevity. With regard to the first point, the possible length of life, we can only form a judgment by referring to the facts which have been recorded during the historic ages, as these only can be applicable to the condition and constitution of man as he at present exists. Within these ages there is no reason to believe that the term of life has essentially varied. The touching words of the Psalmist are probably as true now as when they were uttered nearly three thousand years ago: — "The days of our years are threescore years and ten; and if by reason of strength they be fourscore years, yet is their strength labor and sorrow." This now, as it was then, is the lot of humanity; and with most of those who exceed this period, the continuance is no boon to them, and affords to those around them only the painful spectacle of infirmity, imbecility, and decay.

Yet there have, in all ages, been instances of those who have exceeded this limit; and in some the faculties both of body and of mind have been remarkably retained. The earliest authentic record of such examples is found in Pliny's Natural History, and is given by Lord Bacon in the following words. "The year of our Lord seventy-six, falling into the time of Vespasian, is memorable; in which we shall find, as it were, a calendar of long-lived men; for that year there was a taxing (now a taxing is the most authentical and truest informer touching the ages of men); and in that part of Italy which lieth between the Apennine mountains and the river Po, there were found one hundred and twenty-four persons that either equalled or exceeded an hundred years of age." Among these, four had attained the age of one hundred and thirty years; four the age of one hundred and thirty-six; three, of one hundred and forty; and in a town on the Adriatic, Ariminum (Rimini), one had lived one hundred and fifty years. In modern times, in the empire of Russia, according to official returns, in the year 1828 there were eight hundred and twenty-eight centenarians, of whom forty had exceeded one hundred and twenty years; fifteen, one hundred and thirty years; nine, one hundred and thirty-six years; and three, one hundred and thirty-eight years. According to the same authority, in the year 1830, one person died at the age of one hundred and fifty, and in the year 1844, one aged one hundred and fifty-three years. There are statements of a longevity in the same country even greater than this, but upon less trustworthy authority, — as of one hundred and eighty years, and even more. In the state of New Hampshire, between the years 1810 and 1820, in a population averaging about 225,000, there died twenty-nine centenarians, of whom several had reached the age of one hundred and five, and seven the ages, respectively, of one hundred and six, one hundred and seven, one hundred and eight, one hundred and ten, one hundred and fifteen, one hundred and sixteen, and one hundred and twenty years.

Of individual instances, we find in England those of Henry Jenkins, who died in 1670 at the age of one hundred and sixty-nine; of Thomas Parr, at the age of one hundred and fifty-two, in 1635; and of others, at one hundred and forty, one hundred and fifty, and one hundred and fifty-two. In America, the best attested and the most interesting case of longevity is that of Henry Francisco, of which the following account was published by Professor Silliman of Yale College, nearly forty years ago.

"He believes himself to be one hundred and thirty-four years old, and the country around believe him to be of this great age. When we arrived at his residence (a plain farmer's house, not painted, rather out of repair, and much open to the wind), he was up stairs, at his daily work of spooling and winding yarn. This occupation is auxiliary to that of his wife, who is a weaver; and although more than eighty years old, she weaves six yards a day, and the old man can supply her with more yarn than she can weave. Supposing he must be very feeble, we offered to go up stairs to him; but he soon came down, walking somewhat stooping, and supported by a staff, but with less apparent inconvenience than most persons exhibit at eighty-five or ninety. His stature is of the middle size, and, although his person is rather delicate and slender, he stoops but little, even when unsupported. His complexion is very fair and delicate, and his expression bright, cheerful, and intelligent; his features are handsome, and, considering that they have endured through one third part of a second century, they are regular, comely, and wonderfully undisfigured by the hand of time; his eyes are of a lively blue; his profile is Grecian, and very fine; his head is completely covered with the most beautiful and delicate white locks imaginable; they are so long and abundant as to fall gracefully from the crown of his head, parting regularly from a central point, and reaching down to his shoulders; his hair is perfectly snow-white, except where it is thick in his neck; when parted there, it shows some few dark shades, the remnants of a former century. He still retains the front teeth of his upper jaw; his mouth has not fallen in like that of old people generally, and his lips, particularly, are like those of middle life; his voice is strong and sweet-toned, although a little tremulous; his hearing very little impaired, so that a voice of usual strength, with distinct articulation, enables him to understand; his eyesight is sufficient for his work, and he distinguishes large print, such as the title-page of the Bible, without glasses; his health is good, and has always been so, except that he has now a cough and expectoration."

It appeared from his account of himself, which was consistent and intelligible, and confirmed by collateral historical facts, that his father was a French Protestant, who fled from France in the latter part of the reign of Louis the Fourteenth, in consequence of the persecutions arising from the revocation of the edict of Nantz; that he took refuge in Holland, and afterwards in England; that Francisco himself was born in the year 1686; that he recollects his emigration from France in 1691, and the coronation of Queen Anne in 1702, at which time he says he was sixteen years old. He fought in all Queen Anne's wars, and exhibits the scars of many wounds, but only recollects the name of the Duke of Marlborough, among the commanders under whom he served. He came out with his father to New York early in the last century, though he cannot remember the date, and was engaged in most of the wars which occurred until that of the Revolution. "He has had two wives and twenty-one children; the youngest child is the daughter in whose house he lives, and she is fifty-two years old; of course he was eighty-two when she was born." "He has been all his life a very active and energetic, although not a stout-framed, man. He was formerly fond of spirits, and did, for a certain period, drink more than was proper; but that habit appears to have been long abandoned. In other respects he has been remarkably abstemious, eating but little, and particularly abstaining, almost entirely, from animal food; his favorite articles being tea, bread and butter, and baked apples. His wife said, that after such a breakfast he would go out and work till noon; then dine upon the same, if he could get it, and then take the same at night; and particularly, that he always drank tea, whenever he could obtain it, three cups at a time, three times a day."

Of the duration of the life of animals our knowledge is necessarily less exact. In the Mammalia, it has been supposed to bear some definite proportion to the period of their arrival at the perfect development of their structure. Although no exact relation of this kind has been established, some such correspondence may be found to exist in many cases, and animals which come early to maturity, perish young. Thus the elephant grows for thirty years, and lives nearly two hundred; whilst the horse, after arriving at his full size in four or five years, rarely lives to twenty-five; and the dog, whose growth terminates in two or three years, lives only ten or twelve. Among individuals of our race there is observed some tendency to the same result; those who arrive at the full development of their bodies at an early age are less likely to live long than others.

In Birds, there seems to be no indication of a similar rule. They come to maturity in a shorter time than Mammalia, and yet their lives are, in many cases, longer. The raven has been known to live a century; the goose to attain nearly the same age, and the swan a still greater; and an eagle died within a few years, in Vienna, which was stated to have been in confinement a hundred and four years. All such accounts, however, are to be received with much allowance. The difficulty of ascertaining the truth is great; and the tendency to exaggerate with regard to such subjects is well known.

In Reptiles and Fishes, there is reason to believe that life, in some species at least, may be extended through a much longer period than in warm-blooded animals. Tortoises have been found with dates marked upon their shells indicating that they had arrived at their full growth more than a century before the time of their capture. Still it is most likely there is no general difference in this respect between the warm-blooded and the cold-blooded animals, but that, as in the case of plants, there are those whose existence is very short, as well as those in which it is very long. We have as yet no such exact means of determining the age of any animal as we have of trees, some of which furnish indubitable evidence of an existence and growth of many thousand years.

The life of Insects is short, and even of this short life a considerable portion is often passed in a state of inactivity. In their fully developed condition many of them live but a few days, or even but a few hours; and few of them beyond a single season. When life is prolonged, as in the seventeen-years locust, there is no extension of active and conscious existence, but only of the state of torpidity, — an extension like that recorded of frogs and toads inclosed in rocks or trunks of trees, of dried animals, and of those embedded in ice. There is no proper prolongation, but simply a suspension, of life. The amount of vitality assigned to each individual is not then drawn upon, and is therefore not exhausted. The condition is like that of the seed or of the egg, when removed from the causes of germination as well as of decomposition. Secluded as they are from heat, light, air, and moisture, there would seem to be no necessary limit to the continuance of this condition of latent life in those organized bodies that are capable of enduring it at all.

It would be interesting to determine how far this singular fact with regard to the extension of the term of existence in lower animals may have any bearing upon the circumstances that promote a similar extension of the life of man; how far, for example, habits of life and other causes, that increase the activity of our functions, and thus occasion a more rapid exhaustion of the original stock of vitality, may tend to hasten the period of a natural dissolution. There are many things we observe in the lives of mankind that render such a tendency probable; and it may be remarked as a general truth, that those who are exposed to many causes which we know to be exhausting and depressing,— to causes which produce great and disproportioned activity of the functions, — or those who in any way *live fast*, seldom attain to advanced age. It would be impossible in a limited space to point out all the circumstances which tend to establish this general proposition. It will be sufficient here to point out those which experience indicates as, upon the whole, favorable to long life.

Upon this subject prevalent opinions are very vague, and are liable to be founded upon the observation of special instances. If any peculiarity has been noticed in the habits of a centenarian, this is apt to be seized and dwelt upon as the probable cause of his longevity. One old man, for example, is found to have been an early riser, another a late riser; one to have drunk nothing but water, and others largely of tea, or milk, or rum; one to have been very cleanly, and another the opposite. But it is usually difficult to find, upon a careful examination, any single and distinct thing in an aged person which explains why he should have lived longer than his neighbors. Probably long life is to be attained by the avoidance of causes which tend to shorten it, rather than by availing ourselves of those which can have a direct influence to lengthen it. These causes are undoubtedly many; and as they may have operated very gradually, and at an early period of life, as well as through its whole course, a thorough analysis of them and of their mode of operation is a very difficult, not to say an impossible, task, and we must content ourselves with a very general and also imperfect account of the subject.

There is much in hereditary disposition, and also in the tendency of individual constitutions to longevity. Still what is commonly called a strong constitution, one which insures uniform robust health and freedom from disease, is not always indicative of a tendency to long life. This depends mainly upon the rate at which the capital of life is spent; and it may be spent more rapidly by many habits not inconsistent with generally good health, than by some habitual diseases. This is a distinction important to be made. There is an imperfect condition of many of the functions, producing a constant succession of ailments, and there are even certain diseases of frequent occurrence, which do not appear at all to diminish the resources of the system, — perhaps even, sometimes, to preserve them. Thus many persons whose health has always been feeble survive to a great age. This is partly, no doubt, because such persons have always lived with great care, and have run into no excess or hurtful indulgence. On the contrary, others, who have enjoyed even robust health, have known no disease, and have consequently exercised no control over the appetites, seldom attain to old age.

The general conditions, then, which contribute to long life, are those which do not imply a rapid and unequal exhaustion of those powers by which life is maintained. These conditions are a moderate and an equally balanced performance of all the functions, and a moderate and an equally balanced indulgence of all the natural appetites. So far as this object is concerned, it is less likely to be defeated by a deficient intensity in the functions, or a deficient indulgence of the appetites, than by excess in either; although a greater efficiency in the business of life, and a more perceptible enjoyment of health, may be consistent with the latter.

In regard to particular conditions, that which experience shows most uniformly important is the breathing of a uniformly pure air, with an abundant supply of it; air free from the artificial impurities which pollute the atmosphere of cities, and from those natural ones which prevail in low, flat, damp, malarious regions. Hence mountainous districts, well drained by running streams of water, have always been noted for longevity. The most favorable climate seems to be that in which there exist considerable vicissitudes in the seasons, and which admits of exposure, with due protection, to the bracing air of a cold winter. Although unmitigated exposure to cold is undoubtedly a depressing agency, and productive of disease, yet, within certain limits, it is by no means certain that, like torpidity, such exposure may not prevent the expenditure of vital power.

In regard to food, no condition seems so important as that it should not be immoderate in quantity; and its kind is of little consequence except so far as it may lead to habitual excess. Very old men have for the most part been simple livers and small eaters; and the greater number of them have been of the humbler classes of society, with whom high living was not possible, and the quality of their food did not tempt to indulgence. The influences which operate upon persons of this description are rather those which produce disease, than those which exhaust life; and hence, although there may be among them a greater mortality in early and middle life, there is more reserved power in such as resist the causes of death during this period, to resist also those which operate chiefly in age.

A life of extreme labor, or indeed extreme exercise of any kind, of extreme anxiety about worldly concerns, of extreme moral excitement of any kind, is unfavorable to long life; whilst, on the contrary, a moderate degree of each favors it. Scarcely any-thing seems to contribute more to it than a t habit of mind, and a freedom from annoying cares. But exceptions will be found to all general principles on this subject, as upon all others. Some men live to an advanced age when everything seems to threaten them with an early death; and others, when everything promises an extended existence, are disappointed in their expectation. It is particularly to be remembered, that life is not to be prolonged by deferring the adoption of the necessary means till old age is already approaching. The causes which determine the period of our dissolution may be at work while we are in the midst of health and indulgence; and may be determined, so far as it depends upon natural causes, even in youth or infancy. No doubt where the capital of life has been prematurely expended, excessive care, and a rigid husbanding of what is left, may do somethimg toward a prolongation of our years. Lewis Cornaro, who from fast living was thought ready to die at the age of thirty-five, by adopting a strict and self-denying regimen, lived beyond a century. But it is not wise in matters of importance to be governed by exceptions; and it will be found in respect to health, as well as in our worldly affairs, that it is safer to practise an early economy than a late parsimony, if we would live comfortably in the one case, or long in the other.

CHAPTER XVII. (W.)

ON INSTINCT AND INTELLIGENCE, AND ON THE MENTAL CONSTITUTION OF ANIMALS.

The individuality of everything possessed of life, and the absence of this individuality in everything not possessed of life, were mentioned in the Introduction as among the characteristics by which organic, organized, or living matter is distinguished from inorganic, unorganized, or common matter. This difference is an important circumstance in its relation to the laws by which these two divisions of existing things are governed. The whole [illegible] of inorganic matter, as it respects these laws, constitutes [illegible] On the other hand, each distinct plant and animal, however humble, also constitutes in itself a single system. There is one principle, which, by one uniform set of laws, governs the inorganic material universe as an integral whole. Each living thing is also an integral whole, governed by its own principle, and acting by a set of laws peculiar, in a certain sense, to itself. The gravity which makes a stone fall or a balloon ascend, is the same as that which regulates the motion of a planet in its orbit. The life of the insect has no such community of existence with the life of the man. Every living thing is insulated from every other living thing. The forces by which the operations of any one living system are carried on, have no interchangeable relations with those by which the operations of any other are carried on. Each organism is a unit, in regard to the laws which govern it. Each is shut up in its own individuality. So far as its life is concerned, it can impart nothing, it can receive nothing. It has in itself, and for itself, its own power and its own cause.

This is a remarkable condition of existence. Our own reflections teach us that it is a real one, so far as our conscious powers are concerned; for what can be conceived of as more insulated than the consciousness of each and every man? But it is equally real with regard to every the minutest detail of his structure and his functions. Of this there is a homely, but convincing, illustration in the fact, that even in so slight a matter as the odor of the skin, which is dependent upon an emanation the pecularities of whose composition no chemistry can detect, there are no two individuals so precisely alike that the senses of the dog cannot distinguish one from the other.

The whole universe of inorganic matter, then, constitutes an individual economy, governed by laws, and possessed of powers, which pervade, and are common to, every part of it. Each separate living organism is also an individual economy, governed by laws, and possessed of powers, which pervade, and are common to, every part of its organization, but extend to nothing beyond it. Both in the universe of inorganic matter and in living organisms the economy is directed by an intelligent principle. In the former this is a general one; in the latter it is peculiar to each individual. Among the possessors of life there is a wide difference in the extent and variety of the powers which are exercised; yet they nevertheless always retain this essential characteristic of an insulated individuality. Thus in all plants, and perhaps in some animals, although operations directed by an individual, intelligent power are constantly carried on, there is no sensation, no perception of an external world, and no consciousness of existence; whilst in a large proportion of animals, perhaps in all, each of these is present. Probably in the lower forms of animal life, sensation, perception, and consciousness are dim and indistinct when compared with the intense character which they exhibit in the higher forms; still they exist. But, what is particularly to be observed in connection with the present subject is, that even in these higher animals, beside the performance of operations under the cognizance of sensation, perception, and consciousness, there are also performed other operations, essentially the same with those of plants, of which they take no cognizance, and over which they have no personal control, and yet these operations, like those in plants, are under the direction and superintendence of an individual and intelligent, though still unconscious, principle.

In ourselves, for example, the functions of sensation and motion report themselves to our consciousness; we recognize the organs by which they are performed, and the results they bring about. It is not so with those functions by which the body is nourished and the organs are kept in repair. We do not notice their performance at all, except indirectly; and we do not even recognize the existence of the organs by which they are carried on. Now these functions are essentially the same as those of the plant; and, like those of the plant, they may be perfectly performed without being perceived by the consciousness of the organic being in which they are exercised. We have then, in a limited sense, two principles of intelligent life. Of one of these we are conscious, and its operations are under the influence of the will; whilst of the other we are not conscious, and its operations are entirely independent of the will. Still these principles have not that distinctness from each other which this statement might seem to imply. They have intimate reciprocal relations, a common bond of union; they are indissolubly bound together by a necessary condition of their existence; they constitute a

ONE. Under certain abnormal conditions, we perceive the presence and actions of the organs of the vegetable life within us; whilst, on the other hand, these organs are powerfully influenced by the passions and emotions of our conscious, or animal, life.

From the unconscious, but still intelligent, principle proceed those actions, or operations, which are called Instinctive; from the other principle, the conscious, proceed those actions which are called Intelligent. It is to be observed, however, of many of the latter, that, although they are carried on by the aid of the senses and the voluntary muscles, under the full cognizance of the animal, yet the impulse from which they proceed, and the skill with which they are directed, are entirely out of the sphere of consciousness, and are to be referred to the same source as the functions of organic life.

We may distinguish, then, three classes of operations by which the economy of animals is carried on.

First, Those which are prompted, devised, directed, and executed by the unconscious principle;

Secondly, Those which are prompted, devised, and directed by the unconscious principle, but are executed by the organs of the conscious principle, that is, by the organs of sense and motion, and are often suggested by information derived from these; and

Thirdly, Those which are devised, directed, and executed mainly by the intelligence of the conscious principle.

Of these last operations, however, many are prompted by suggestions from the unconscious life, and are often executed by means not to be distinguished from those by which that life is administered. So, also, voluntary actions which have become habitual are not easily to be discriminated in their mode of performance from those which are instinctive, and, on the other hand, purely instinctive actions resemble closely those which are the result of habit. The artisan who devotes his life to the practice of some very nice and complicated workmanship, and the musician who executes on a piano-forte two or three parts of a complicated harmony, are not unapt representations of the bee or the wasp, going through with their tasks, adapting themselves to circumstances that may arise, and devising, within certain limits, means to obviate occasional difficulties with equal skill.

There is such a combination of these two principles of activity in most of the operations of the life of animals, especially of the higher, that it becomes extremely difficult to analyze their character and to determine from which they proceed. Even in man, where instinct has the least, and intelligence the most, influence upon these operations, it will be found that the former takes a larger part in them than we are apt to imagine, though still a part subservient to, and directed to, the purposes of the latter. Thus, in voluntary motion, there is no muscle of the body which we can cause to contract by a simple act of the will, directed to it with this specific purpose. We will the hand to grasp an object, and are sensible of the consequent effort in the hand, but of none in the muscles that move the hand; for these are situated at some distance, and, unless instructed by a knowledge of anatomy, we have no idea where. We will to hold our breath; but this we do, not by willing the cessation of the action of the muscles by which respiration is performed, but by interposing a mechanical obstacle to the entrance of air, by an effort directed to quite a remote part, the aperture of the windpipe.

It is also true of some of those higher operations which appear most exclusively in the domain of the intellect, that in the instruments and mode of their performance the instinctive or unconscious element enters largely. Thus, in operations which relate to numbers, although the intellect is wholly concerned in the conception of the object of the process and the general course of procedure, the subordinate steps of the process are performed instinctively. This is so much the case, that those individuals in whom the capacity for numerical calculation is carried to excess as part of their original constitution, Zerah Colburn for instance, are incapable of explaining the steps by which their results are arrived at; — they are reached by a species of instinct. So, too, the education of the senses and of the voluntary muscles in infancy is carried on by a species of instinct, rather than by a voluntary process set on foot by the conscious intelligence, with this definite purpose in view. The same is true of the original acquisition of language. The original tendency, and the first steps taken, are properly instinctive, though the voluntary and intelligent principle begins sooner or later to take charge of the process, the final direction of which is mainly under its guidance.

There is a close resemblance between the remarkable results of the instinctive principle as exhibited in the voluntary labors of some insects, and those which are produced by the involuntary labors of the internal organs. The hexagonal cells of bees and wasps, and the arrangement of their combs, have their counterpart in the structure of the electrical organs of the torpedo, and of one of the stomachs of ruminating animals. This comparison may appear fanciful; yet, on a careful consideration, it is difficult to point out any real distinction, except in the organs by which the work is performed. In both cases it must be directed by some principle working with intelligence to accomplish a determinate end. The only difference is in the agents by which the work is done, in the one case by those internal ones which fabricate all the organs of the body, in the other by the organs of sense and will, but all equally under the guidance of the instinctive intelligence conveyed by the nerves to the parts concerned. The mere fact that the operation is not present to the consciousness in the former case, whilst it is in the latter, does not alter its essential character, since in the latter the conscious intelligence of the animal is not supposed to take any part in its direction.

The same analogy may be pointed out with regard to a still more remarkable example of pure instinct. As formerly stated, there are certain insects which not only provide a place of deposit for their eggs, but also store it with a supply of food adapted to the necessities of the young after they have been hatched, — a kind of food entirely different from that by which they are themselves nourished. There is no operation in insect life, which, if performed by a rational being, would seem to indicate a more varied capacity and knowledge than this. It would imply a knowledge of the office in which it was engaged, — namely, the production of offspring, — of the difference between this offspring and itself in its condition and necessities, and of its incapacity to provide for these necessities. Now there is, in our own species, a similar provision, by which, months before the birth of the infant, an organ, the mother's breast, is put in a course of preparation for the manufacture of food for his nourishment after the birth takes place, a food peculiar in its qualities and different from that of the mother; so too in the jaws of the child itself, before it comes into the world, the teeth are already formed to act upon a still different kind, for which it will have no desire and no power of digestion, till after a long period. In both these cases there is somewhere, belonging to the individual organism, knowledge, forethought, sagacity, applied to bring about certain ends almost identical in their nature and conditions with those in the case of the insect. We do not believe that the insect has any personal conception of the work he is about, he is simply a conscious and voluntary agent of a blind impulse; in the cases of the mother and the child, the impulse is the same, it differs only in the character of the agents by which the work is done.

In the different grades of instinct are found great differences as to the amount and extent of the powers of intellect which are associated with them in the government of the economy. When this is wholly managed by instinct, there seems to be no capacity for acquiring knowledge; all the knowledge necessary to the performance of the functions is innate, for the bee knows as well at the first moment of its existence all those qualities of external objects which fit them to make wax and honey of, as it does after the experience of a season. Animals of a higher grade are found with a less perfect instinct and less innate knowledge, but with a power of acquiring knowledge, till we come to man, in whom no knowledge is possessed at birth, but a high capacity for its attainment.

The investigation of the directing powers of animal life is attended by greater difficulties than almost any subject that can be presented for our consideration. It is even more obscure than that which concerns our own mental constitution; since in the latter case we have the aid of our own consciousness to guide us, as well as language, which affords a means of communication with the consciousness of others. A perfectly satisfactory explanation of the facts of instinct and of intelligence, and a reference of their respective phenomena to each, is not to be expected; but the above statement affords perhaps as intelligible a solution as can be given. The subject may be further illustrated by considering some examples of the manner in which the powers that direct the operations of living things exhibit themselves in various forms of vegetable and animal life.

The tendrils of climbing plants throw themselves out in a straight line till they touch some object, and then immediately begin to twist around, seeking to attach themselves in order to support the stem. "It is a hand seeking in the dark, and grasping what it has felt by an action remote from the sensible point." "Among a collection of palm-trees was one having hooks near the extremity of the frond, evidently designed for attaching it to the branches of trees for support when growing in its native forests. The ends of the fronds were all pendent but one, which, being nearest to the rafters of the conservatory, lifted its end several feet to fasten to the rafter; none of the others altered their position, as they could not have reached the rafter had they attempted to do so." The Pandanus, or screw-pine, as it increases in size, is supported by aërial roots which are thrown out at some distance from the ground, and, when they reach it, soon bury themselves. When, however, a tree inclines to one side, these roots are developed on the opposite one at some distance above the others, in order to counteract the increased danger of being blown down by the wind. One of the varieties of Indian corn attains to a height of twelve or fourteen feet. In order to support this disproportioned growth, the plant throws out fibres at various distances from the ground, which, descending, take root, and support the stem like the shrouds of a mast. This is not an expedient common to all varieties of the plant, but a peculiar one adapted to the necessities of this.

The phenomena observed in connection with the complicated economy of the social insects, — bees, wasps, and especially ants, — have been described in several of the preceding chapters. So remarkable are they, and so indicative of observation and reason, that we find it difficult to regard them as the results of anything else. Yet phenomena equally complicated, and equally indicative of these qualities, are exhibited in the internal economy of that wonderful fabric, the human body. In the harmonious performance of its many functions; in their nice and intimate correlation; in the constant variations of the intensity of the action of the several organs, according to the necessities of the system or of particular parts of it; in the perception of the operations of external agents, and the consequent reaction; and in the sympathy between remote parts, — we have a system as complex, and yet regulated in as orderly a manner, as in the beehive or the ants' nest. If the flow of perspiration from the skin be defective, the kidney supplies the defect; if the secretion of the liver be disturbed, the same organ again interferes to ward off the evil results; if any organ, from its increased activity, requires an increased quantity of blood, the heart and bloodvessels immediately supply the demand, and, as this process calls for an augmented respiration, the muscles of the chest take on a more rapid action to introduce a corresponding quantity of air; if an injury, however unusual, be inflicted, the agents that have charge of this office, rush at once to the work of repair; whilst in some animals, if even a whole limb is torn off, a new one is manufactured to supply its place, with all the appropriate details of its structure, — bones, muscles, vessels, and tendons. The combined operations in the one case appear as much the result of a common presiding intelligence as in the other. The difference, as before explained, lies in the fact, that, in the former, the agents are conscious and voluntary; in the latter, unconscious and involuntary. There is no reason, therefore, for believing that any other directing powers enter into the production of the phenomena in question, than those which are properly instinctive.

But when we come to the higher animals, the case is different. The insect is born with all the knowledge, as well as all the powers, that are necessary to his purposes. He is as adequate to the labors he is to perform, the moment he comes into life, as he is when he goes out of it. He learns nothing from observation; he acquires no skill from experience. Neither of them teaches him to modify, or improve, or advance upon, the suggestions of his instinct. But the higher animals, though they come into life with various instincts, and often with much of the knowledge that is necessary to carry them into active operation, are capable, by observation, experience, and reflection, not only of modifying and improving them, of carrying them out more perfectly as they grow older, but also of applying them to subjects which do not originally fall within their province. Indeed, especially under the influence of education, they may be made to undertake operations which are entirely out of the sphere of instinct.

The habitations of animals are mainly constructed under the direction of a clearly marked instinct, which not only dictates the general form of the structure, but also many of its details, and the materials to be employed. The most remarkable example of this instinct is found in the beaver. Its strong original tendency in this direction has been exemplified in the case of a young one, made captive before he could have learned anything by observation. As soon as he was released from his cage, he busied himself in a structure which bore a certain resemblance to the dam and cabin that these animals build in a state of nature. He had recourse for this purpose to whatever materials chance threw in his way, such as brooms, brushes, sticks, baskets, books, shoes, and boots. While at his work, he much resembled a child playing at building houses. Still this instinct is not absolute and undeviating, like that of the bee and the wasp; it is modified according to circumstances. In the neighborhood of human abodes, the beavers neither associate nor build their peculiar habitations; and, when the water they have selected as the seat of their colony is permanently at the same level, they make no dam. It is only when they have made choice of a running stream that their instinct is allowed full operation. Observation and experience teach them to restrain its impulses wherever the circumstances are such as to render its full indulgence unnecessary, inappropriate, or dangerous.

The mysterious migrations of birds, especially that most remarkable one of the wild geese, appear as if they were under the guidance of an unobservant and inexperienced instinct, an instinct operating like that of the bee, which finds its way home with so much certainty, even when abroad for the first time, and is so discreetly observant of the state and aspects of the weather. Earlier in some years, and later in others, the wild goose starts upon his journey for the arctic regions, guided by some principle more certain than the compass or the sextant. He is accurate in his calculations of season, climate, and distance. He anticipates, more certainly than man can do, the character of the coming weather, and, according to his anticipations, returns early or late to the kindly waters of the South. What foresight, what intelligence, what wisdom! But there is no other subject to which he can apply them. For all other purposes these marvellous powers are dormant. The intelligence by which he is guided seems more like the power of the needle to point always to the pole, than an actual voluntary judgment, which, if it existed in man, he would be capable of applying to a variety of other subjects. But we have other examples of animals finding their way from place to place, not by a general law of instinct belonging to the species, but by an exhibition of sagacity peculiar to the individual, and due apparently to its own observation and reflection. Such are the cases, so often narrated and so well authenticated, of cats, dogs, and horses, which, after being carried a long distance from home, have, without any possible aid from man, found their way back.

It is not to be denied that, even among those animals which according to the preceding statements are to be regarded as governed exclusively by instinct, there are occasional exhibitions of sagacity that are difficult to account for, except upon the supposition of observation and reasoning. A small black ant in South America, inhabiting a district subject to frequent inundations, builds its hills about three feet high, in the near neighborhood of each other. When the water rises above them, the inhabitants commit themselves to the waves, clinging together in a large, thick mass, and thus float upon the surface. This mass they attach to some plant or sprig of grass, in order that they may be kept stationary till the inundation subsides; and thus they readily find their habitations again. But on the other hand, in the same class of animals, we also find examples of an instinct so blind, and sometimes so destructive to them, as to preclude the idea of any proper observant or reasoning power. It is related of a tribe of ants in Sierra Leone, that they march always in columns, and pursue obstinately a straight course, from which nothing ever induces them to deviate. If they come to a building, they either go over or undermine it, and if to a river, they endeavor to cross it, although the attempt is attended by the destruction of vast numbers.

The apprehension of danger operates as a strong motive for the exercise of the latent powers of animals, and under its influence they are stimulated to the devising of extraordinary expedients for escape. Of this, several remarkable instances are referred to in the preceding pages. One of the most marvellous is the feigning of death. This has been observed in the elephant, the crocodile, the opossum, the hedgehog, the fox, and probably in others. In these animals, it is rather the special stratagem of the individual, than the result of any general power. It has, however, been also observed in some insects, and in them appears less like a device of the individual, than an impulse belonging to the race.

Many of the domestic animals, and of others when associated with or educated by man, afford unequivocal evidence of no small degree of sagacity, observation, and intelligence, combined with and modifying the operation of instinct. This has been particularly observed in elephants, dogs, and horses, but sometimes in animals less remarkable for capacity, as cats, camels, hogs, goats, and seals. Cats have been often known to open a door by springing upon a thumb-latch, horses to untie their halters with their teeth, cows to let down bars and to open gates. There is here implied a nice observation of the manner in which they have seen these operations performed; a distinct cognizance of the means employed, and of the mode in which they bring about the end; and finally an imitation of those means.

There are other cases which display a closer approach to the processes of the human mind, and imply a more complicated series of observation, reflection, and analysis. A cart-horse, noted for his sagacity, once found a wagon obstructing the way which led to his stable. The space was too narrow to allow him to pass on either side. Placing his breast against the vehicle, he pushed it onward till he came to a part of the road which was wide enough to allow him to go by it. On another occasion, a large, wide drain had been dug in the same road, and planks laid over it, on which he could cross. It was winter; and one morning the planks being covered with snow and ice, in stepping upon them his feet slipped. He drew back, and seemed at a loss how to proceed. Near the planks was a heap of sand; he put his fore feet into this, and looked wistfully to the other side of the drain, where stood the boy who was accustomed to attend him. Seeing his hesitation, the boy called him. The horse immediately turned round, and, first with one foot, and then with the other, scraped the sand over upon the planks till they were completely covered. He then, without hesitation, trotted directly into his stable. Some horses kept in an inclosure together, were supplied with water by a trough which was filled from a pump. One of them learned, of his own accord, to supply himself and his companions by taking the pump-handle between his teeth, and working it with his head. The others, finding that he could thus supply their wants, would force him, by biting and kicking, to pump for them, and would not allow him to drink till they were satisfied. "That this was not a mere act of imitation," says Dr. Carpenter, who tells the story, "appears from the circumstance that the horse did not attempt to imitate the movement of the man, but performed the same action in a different manner." A wren, in the Penrhyn slate quarries, used to fly from her nest on the ringing of a bell, which gave notice to the workmen engaged in blasting that an explosion was about to take place. In order to exhibit this phenomenon to strangers who visited the place, the bell was often rung at other times. At first, the bird left her nest as before, but after a time, paid no attention to the signal, except when she observed that the workmen also went away as they had usually done.

There are other well-attested anecdotes which tend to show, that animals are not only guided in their actions by faculties like those of men, but are also excited to action by some of the same feelings and emotions. The following is given on the authority of Cuvier, and derives an additional interest from the fact that it first served to draw his attention to Natural History, as a pursuit. While he was a young man, a pair of swallows built their nest on one of the angles of the casement of his apartment. During their temporary absence it was taken possession of by a pair of sparrows, who persisted in retaining it, and resisted every effort of the rightful owners to regain it. After a time, crowds of swallows gathered upon the roof, among whom were recognized the exiled pair, who seemed to be informing their friends of the outrage they had suffered. The whole assembly was in a state of great commotion, and appeared highly incensed, as was manifested by their movements and cries. Before long, suddenly and swift as thought, a host of them flew against the nest. Each bore in his bill a small quantity of mud which he deposited at its entrance, and then gave way for another who repeated the operation. This was continued till the opening was completely closed up, and the marauders were buried in a living tomb. The labors of this friendly company, however, did not cease here. They immediately collected materials for another nest, which they built just over the entrance to the first. In less than two hours after the act of vengeance had been consummated, the new structure was completed and inhabited. In an English park were two large pieces of water separated from each other by an isthmus much wider at one end than the other, and inhabited by a couple of swans. A fawn and its mother, belonging to a herd of deer that inhabited the park, on coming one day to drink, were attacked by the swans, and the fawn was drowned. Some time afterward, when the swans were both upon the widest part of the isthmus and thus at a distance from the water, a number of deer rushed suddenly down, and trampled one of them to death. A small dog which had been repeatedly worried by a large one, at length brought to his aid a dog still larger, who so effectually chastised his enemy as to put a stop to all future aggression. These are striking examples of a distinct motive, a distinct plan, a power of communicating that plan to or of devising it in common with others, of inspiring them with a common sentiment, and finally of carrying the plan into execution with their aid.

The maternal instinct, when excited by circumstances to a more than common intensity, has been sometimes known to lead to the exhibition of unusual discernment. A cat had had several successive litters of kittens successively drowned. At length, apparently in despair at this repeated blasting of her hopes, she prepared a secure place at some distance from her usual place of abode, and there her next litter was brought forth. This was finally discovered, but her affection and ingenuity were this time rewarded by the lives of her offspring. The nest of a martin had fallen from the eaves of a house when full of young. These were taken up and placed in a basket, where their parents attended and fed them as before. All were fledged, and soon left their place of refuge except a feeble and helpless one which remained there. When thus left alone he was exposed to the severity of cold east winds, which began to prevail at the time. The old birds not only continued to supply him with food, but, in order to protect him from the wind, built up a wall of mud three inches high, upon that side of the basket which was exposed to it. The following case furnishes a rare example, at once of the ingenuity suggested by the maternal sentiment, and of fidelity to an accustomed duty. A shepherd intrusted a flock of eighty sheep to his dog alone, to be driven home, — a distance of seventeen miles. On the road she was delivered of a couple of pups. Notwithstanding this incumbrance, and though still faithful to her maternal instinct, she was not neglectful of her task. By carrying her young a few miles in advance of her flock whilst it was feeding, and then driving it on beyond them, she at length reached the end of her journey; as it turned out, however, at the sacrifice of the lives of her offspring.

A feeling of kindness between individuals of the same species is sometimes the motive which prompts to these unusual exhibitions. A wounded or imprisoned bird has been sometimes fed by its fellows. When the dugong, a gregarious animal, is wounded by the harpoon, its companions flock around and endeavor to wrench out the weapon with their teeth. Still it more frequently happens among animals, when one of their number is maimed or helpless, that it is either neglected, or else trodden down or even devoured by the rest.

Attachment of animals to particular individuals among mankind is a more common sentiment. A horse came home without his driver, but, instead of going directly to his stable, stopped at the house, neighed, and exhibited other indications of great disquietude. This at first excited no attention; but, as these manifestations continued and his master did not appear, apprehension was excited, and a person despatched in search of him. He was found two miles off, lying insensible in consequence of a severe blow upon the head which he had received by falling from his cart. By no animal has this sentiment been so remarkably evinced as by the dog. A poor boy was fatally injured, and carried to a hospital. His little dog followed him thither, and, being prevented from entering it, lay down at the gate, watching with wishful eyes every one that went in, as if imploring admittance. Though constantly repulsed by the attendants, he never left the spot by day or night, and died at his post even before his master.

The dog of the French soldier follows him to the camp, often accompanies him into action, and has been found at his side when wounded or dying on the field of battle. A private was condemned to be shot and his executioners were ready to fire upon him. Just as the bandage was about being placed over his eyes, his dog flew into his arms and began to lick his face. This touching incident for a few moments arrested the proceedings; but after a short delay his comrades, with tears in their eyes, gave the fatal volley, and the two friends expired together. A youthful conscript, desperately wounded in battle, was conveyed, indiscriminately with hundreds of others, to a hospital. In the course of a few days a little dog made his appearance, and, searching amidst the dying and the dead, discovered at length his expiring master, and was found licking his hands. After his death a comrade took charge of the faithful animal, but no kindness could console him. He refused all food, pined away, and died. Many examples are on record of a similar devoted attachment ending only with life; and, although they afford no evidence of special intelligence, they do of a sentiment of the same nature as that which may exist in ourselves, and which is rarely exhibited of greater intensity.

Phenomena are sometimes observed among animals, of which, from the difficulty of penetrating into the intimate nature of the impulses by which they are governed, it is impossible to discover the motives or the purpose. Huber witnessed among ants strange exhibitions of what appeared to be games for exercise or amusement, or like an imitation of their manœuvres in actual encounter with their enemies. A couple of robins had been often observed playing together in a manner somewhat peculiar. "One day," says the relater of the anecdote, "I had occasion, in the summer time, to look for something in this room, and, accompanied by one of my sons, I unlocked the door with the intention of entering, when two robins flew out through the open, grated window, and then, making a circuit through the air, pitched together on the ground of the court in which we were standing, about ten yards from us. They then apparently commenced a most furious fight with each other, and shortly one of them fell upon his back, stretched out his legs, and seemed perfectly dead. The other instantly seized him by the back of his head, and dragged him several times round and round a circle of seven or eight feet in diameter. Much to my astonishment, after being dragged a few rounds, the fallen and apparently dead bird sprang up with a bound, his antagonist in his turn fell upon his back, stretched out both legs in the apparent rigidity of death, and his late seemingly dead opponent in like manner seized him by the head, and after dragging him a few rounds, they both sprang up and flew off together."

In the inferences we draw from anecdotes recorded of animals, however, we are to bear in mind that they are liable to be tainted with much exaggeration, and that their details are liable to be somewhat colored by the imagination and preconceptions of their relaters. We are to recollect also that the qualities they describe are not to be always taken as indications of the general character of the animals to which they relate, but rather as exceptions to it. The individuals by whom such qualities are exhibited either may be uncommon specimens of their species, or else they may have been stimulated at the time by some unusual motive. We do not find the same display in the ordinary course of their lives. They seem to act at the time under the influence of a sort of inspiration, whilst on all other occasions they display only that amount of intelligence or feeling which is possessed by the average of their race. We sometimes perceive in ourselves, when actuated by some strong sentiment, or in some unusual emergency, that our faculties are quickened to efforts not only more energetic, but directed by greater ingenuity and sagacity than we manifest under ordinary circumstances.

Were the elephant possessed of an original sagacity like that which he exhibits on the few subjects to which his education is directed, a sagacity of general application, like that of man, he would be easily able, in his associated state when wild, to foil the stratagems of his captors, and in a domesticated state to set his masters at defiance. Take him out of the range of these subjects, and his general intelligence is not above that of a small child. In his wild state he is timid and imbecile. He feels no spontaneous impulse to the exercise of his ingenuity or intelligence. His want of observation is shown by the fact that the slightest impediment deters him as completely as the most formidable. Although his immense strength, when instructed, and directed in its exercise, enables him to batter down a strong gate and push over a heavy wall, he will not of himself break through a slight paling which protects the corn-field which he seeks to enter. The feeblest structure in the form of a fence foils him. He wanders round for some unobstructed opening, and, if he does not find one, retreats without attaining his object. He amuses himself with such petty tricks as demolishing the pillars of water-pipes, breaking off their stopcocks, and pulling up the pegs of surveyors. He has no knowledge of his real powers. His own nature does not lead to their development; it furnishes no motive for their exercise. It is only when educated, when induced to acquire knowledge by man, that he exhibits those extraordinary qualities for which he is so celebrated. The same remarks hold true of other animals noted for the occasional display of unexpected capacity.

The results of an examination into the nature of the powers by which the operations of animals are carried on, may be briefly summed up in the following manner. They are under the direction of the two principles, Instinct and Intelligence. Some animals are directed wholly by the former; none wholly by the latter. In most of them the former is the original and fundamental principle of activity, in many it is the only one. In those where it is the only one, it governs not only the functions of the vegetable or organic life, but also those of the animal life, of the senses, the consciousness, and the will, — and its manifestations thus come under the cognizance of the individual. It is originally endowed with all such knowledge as is necessary to the perfect performance of the operations which it superintends, and consequently it is never improved by observation and experience. It does not think, it does not reason, it acts without any reference to an end, it does not perceive the object of the actions it excites. In those animals in which Instinct is not the sole principle of activity, Intelligence enters in various degrees, partakes its dominion, and coöperates with it. Intelligence has no preconceived ideas, it is destitute of any original knowledge, but it acquires both ideas and knowledge. It thinks, reasons, judges; perceives the purpose for which it acts, and in this way renders the instinctive powers, with which it is associated, subservient to its ends; enlarges the sphere within which they operate, imparts to them new impulses, and suggests to them new motives for activity. Instinct, within the field which it embraces, is the most certain guide; but its original field is limited, and without the aid of Intelligence it is incapable of extension. With this aid it may be modified and improved, and the modification and improvement may be transmitted in some degree to succeeding generations. We have the most complete specimen of what Instinct alone can do, in such insects as the ant, bee, wasp, and spider; and of what Intelligence can do, in such animals as the horse, dog, beaver, and elephant, and, more than all, in man. Instinct probably predominates in all animals below man, and the presence of a true Intelligence is not distinctly detected below the Vertebral animals, except among the higher species of the Articulata and Mollusca. Its influence becomes more marked as we ascend, through Fishes, Reptiles, and Birds, to the Mammalia; but it is only among the most elevated of the last that it assumes an important rank as a directing power, and it is never a predominant one except in man. This statement will be sufficient to show what a variety in animal character the influence of these two principles mingled in different proportions must produce, and to show also how difficult in each instance it must be to determine from which of them any given line of conduct on the part of an animal proceeds.

Out of those animals, however, of whose character we have the best opportunity of judging, the insect, as has just been intimated, may be taken as the representative of instinct, and man as the representative of intelligence; for though instinct enters largely into his constitution, yet its range is limited, and though he is constantly influenced by its impulses, and employs it as an instrument, his life is but slightly governed by it. His predominant and governing principle is intelligence. The insect, as soon as it arrives at the perfect state, is capable of all of which it is ever capable. It goes through no education, it makes no improvement, it does not learn by experience, it is taught nothing by its parents, it teaches nothing to its offspring; nothing is transmitted from generation to generation. The race is where it was thousands of years ago. On the contrary, at birth Man knows nothing; he can do nothing. He has only powers and tendencies which are latent. Beginning by actions which are instinctive and an education which is also instinctive, his intelligence becomes gradually developed, is informed by observation and experience, and at length assumes the principal control over his life. He learns from his parents, he teaches his children, and the accumulated treasure of one generation is transmitted to the next.

Man thus stands on an eminence high above all other animals; and yet, so far as we are able to analyze their character, their faculties are not specifically distinct from his, but appear to differ from them rather in degree than in kind. Animals exhibit the same sentiments, the same affections, the same emotions, the same passions as man. Their lives are governed by certain motives and are directed to certain objects in common with his. It is true that man is induced to activity by a multiplicity of other motives which seem to be above their capacity to comprehend, and he seeks to attain many objects, of the value of which they have no conception. We never find in them the love of the sex as the foundation of the family relation, the love of offspring or of parents as a permanent sentiment, the desire of knowledge for its own sake, the love of power or fame, the propensity to accumulate property, the effort permanently to better their condition in any way. These are incentives which stimulate man to that progress which so eminently distinguishes him in creation. Yet it is by no means certain that a minute analysis of the minds of animals might not detect in them the undeveloped embryo of all these characteristics. The degree in which they govern man sufficiently explains his vast superiority as an animal, but they do not account for that essential distinction which we feel to exist between him and the whole living creation around him.

This can only be explained by the possession of an essential distinction in his nature. In man a new and distinct principle is superinduced upon the principle of Life, just as the principle of Life is superinduced upon that which governs inanimate and inorganic matter. Life in its highest conscious and intellectual development explains all the facts of human existence up to a certain point. Beyond that it explains nothing. To the spiritual nature of man, including the moral and the religious sentiment, the mere animal makes no approach. There is not in him the faintest idea which could by growth and development be elevated to a comprehension of it. Of moral distinctions, purely such, no animal has, or can be made to have, the most distant conception. The idea of right and wrong, of good and evil, as such, no amount of education can impart to him. The dog can be taught that killing sheep is wrong, so far as the approbation of his master is concerned; he may be made to feel love, hate, pride, jealousy, shame, and even remorse of a certain sort; he may be governed by the hope of reward and the fear of punishment; but no such idea of an essential moral distinction can be conveyed to him as can be impressed upon and comprehended by a child, long before he is regarded as the subject of moral responsibility.

Of this difference between ourselves and animals we have an almost intuitive perception. We recognize it at every moment of our lives. When do we ever consider an animal as the subject of praise or blame, as having done right or wrong, as having a conscience, as responsible for his actions (with any approach to the same sense in which we do a human being), any more than we do a stone or a crystal, a chair or a table? If we witness, in a community of animals, hatred, revenge, robbery, cruelty, child-murder, and incest, we are moved with no horror, we feel no disapprobation, the idea of wrong never enters into our minds. But, if we are told of precisely the same state of things in a community of men, words can hardly express the horror and disgust with which we are filled at the exhibition of so low and degraded a condition of our species.

If this be true with regard to the moral sentiment, it is, if possible, even more so with regard to the religious. No animal has the faintest conception of a power superior to that of man. He is the only God of the dog, the horse, and the elephant. Different opinions may be held concerning the origin of this sentiment; of its universal existence there can be no question. It may be attributed to an original instinct, to the convictions of reason, to a primeval revelation; it may exhibit itself merely in the form of some vague supernatural fear, some indistinct superstition, some unintelligible idolatrous rite; but, however it originated, and in whatever way exhibited, wherever we find man, there we find it in his possession. It is this which gives to the powers he possesses in common with other animals their onward and upward direction; it is this which imparts to him the new motives that stimulate him to a continued career of progress and improvement; and thus it is upon this element in his nature that depends his immeasurable superiority to every other creature.

CHAPTER XVIII. (W.)

CONCLUSION.

The Kingdom of Life presents a vast collection of objects, which vary almost indefinitely in their character, and yet present so many points of resemblance in the midst of their multifarious differences, that we cannot fail to recognize them as all belonging to one common system, allied to each other as the component parts of one great whole, and proceeding from some one uniform cause always consistent with itself in the principles on which it acts and the end at which it aims. The subjects of this kingdom constitute a series beginning with those of a low and imperfect organization, and rising gradually to those of an organization higher and more perfect. In its general plan, the course which creation has taken from its beginning appears to have been that of progressive improvement, bringing out in the first instance the humblest and simplest forms of life, and then gradually introducing in the midst of them those of a higher and more complex character. Corresponding to this, there are found in the assemblage of living things, as they now present themselves, representatives of all the different stages through which creation has passed from its beginning; so that the study of the chain of life as it is now exhibited is, at the same time, a study of it as its several links have been wrought and bound together in successive periods of time. In a certain sense, then, we have the privilege of looking at the events of creation both historically and contemporaneously, and thus of studying them by a double light.

But though this is the general order of creation, there are found many departures from a perfectly regular sequence. The series does not go on uninterruptedly; there are frequent departures from it in various directions. The line of succession does not proceed in unbroken regularity, either in the order of time, or in the relation which the individuals of the existing creation bear to each other. A lower race seems sometimes to have come into existence after a higher, and creation, after advancing to a certain point, to have taken some steps backward. Among living animals there are found in every class examples of those that combine in themselves some of the attributes of such as are either above or below them. These attributes serve to connect them with other classes, and thus interfere with well-defined lines of demarcation. Among the Mammalia, bats fly like Birds, and whales swim and inhabit the water like Fishes. Among Birds, some can only walk or run, and others can only swim. Reptiles and Fishes in some instances approximate the power of flight, and in others produce their young alive. In some animals, the respiration is at one period of life like that of Fishes, and at another like that of Reptiles; in others, the two modes are always united together. In some, different attributes are so combined that it has been found difficult to arrange their place in a scheme of classification.

But, notwithstanding this, we do not fail to recognize in the history of creation, whether we trace it backward to its beginning, or study it in the forms of life as they now exist, a system, of which the essential element, the characteristic feature, is progress and improvement. This general plan is distinct; and it should make no difference as to our views of its connection with its great Author, whether we regard it as the result of successive distinct exertions of his power, with the constant superintendence of his wisdom and goodness, or of a law impressed upon matter in its original constitution, and producing this system of things by a process of gradual development. The ultimate results are the only true exponents of the character of their cause; and we are to receive the works of nature around us as containing in themselves the written history of their Author, whatever opinion we may be led to form of the course and the instruments he may have seen fit to adopt in bringing them into existence.

Still, those views which represent the creation as his continuous work, which recognize his connection with it as immediate and constant, which imply that the power, wisdom, and goodness, that have brought it into existence, have not resigned it to the control of an intelligent, impersonal, and irresponsible law, but have always continued, and will always continue, to take a direct interest in it,—are certainly most congenial to those sentiments by which he has distinguished our nature from that of other animals. The creature is responsible to his Creator; with reverence be it said, the Creator is no less responsible to his creature. The capacity to fear, reverence, and love an Infinite Being, which we find within ourselves when the idea of such a Being is once fairly presented to our minds, implies the existence of such a Being to be feared, reverenced, and loved, for no other could have imparted such an idea. It were a violation of the eternal and necessary bond which exists between the Maker and his works, that such a sentiment should have been implanted in us when the corresponding reality did not exist. The moral and religious elements in man are as much a part of his nature as those elements which he has in common with other animals, and are as much a part of his natural history as the instincts of the bee and the beaver, or the intelligence of the dog and the elephant, are a part of the natural history of those animals. We may, in conclusion, derive advantage from tracing the connection which the nature of man, as an animal and as man, has with that of the system of things in which he is placed, and also the connection which his Creator has borne to it.

The words of science, as well as of Revelation, teach us, that in the beginning "the earth was without form, and void." In this, the first stage of its creation, it was unfit for the residence of living things. It presented nothing but inorganic matter and its laws; chemical laws governing its elements, physical laws governing its masses. Its temperature was uncertain, unequal, and extreme; its atmosphere unfit for the support of respiration; its surface not yet converted into a soil which could support vegetable life, or, to which this is necessary, animal life. This era seems to have been extended through an immense period of time, occupied by a perpetual action and reaction of different agents among themselves, sometimes violent, sometimes moderate, the result of which was the establishment of such a condition of the surface, such an equilibrium of temperature, and such a constitution of the atmosphere, as rendered the earth capable of supporting life. Plants and animals were then introduced, but at first only in their lower forms; for it was only the lower forms which could endure the imperfect condition of the residence in which they were placed. As this condition was improved by continued changes and successive revolutions, higher forms were created corresponding to this improvement. This progress does not appear to have been uniformly upward and onward, but irregular and interrupted. The repeated destruction of the whole or a part of living things, rendering necessary a new creation, seems to have been occasioned by the conflict of mere physical agents, which continued after life had been introduced, causing various revolutions upon the surface, such as the breaking out of volcanoes, changes in the level of the sea, the subsidence of tracts of land, and the upheaval of mountains. Still, in spite of all interruptions in the course of events, a gradual progress was made toward higher developments of life.

Thus, then, with difficulty life maintained its hold in creation and produced its higher forms, against the force of the chemical and physical agencies whose tendency was to destroy them. When life began, a contest began. Often repressed, often extinguished over wide fields of its operations, life seems to have worked steadily on against its apparently mightier enemy, but to have attained only a slow and laborious victory. How long this contest lasted, it is impossible even to conjecture. We know, by indelible marks, that centuries must have been occupied in the production of some particular change in the earth's surface which seems to our eyes minute and limited; and yet these centuries are but moments in the enormous period which must have been occupied by a long series of changes of which we have equal evidence. The imagination cannot grasp, nor can numbers express, the indefinite durations comprised in these two eras of the world's history, before and after the introduction of life.

Even yet this contest continues. The relation of living to inorganic matter is always antagonistic, and it always must be so. "Life is a forced state." How narrow, even in the world which it has entered, are the regions within which it is confined, compared with those that are still exclusively under the control of physical laws! Life is not possible except for a small distance above and below the surface of the earth; and, even in this contracted space, what vast regions are there whose condition does not admit of its presence, or where only the very lowest forms of it can exist.

How feeble a power life is, in a direct conflict with the physical energies of nature, is shown by innumerable examples around us. It is shown by the destruction of so many races of living things, of whose remains some portions of the earth's crust are almost entirely composed. It is shown by the presence, in other portions, of the fossil remains of other races, whose scattered fragments afford indubitable evidence of their existence and of their disappearance. It is shown by the enormous sacrifice of infant life in all animals, from exposure to physical conditions that are incompatible with its continuance; and by the necessity for innumerable provisions in the structure and functions of all living things, intended to guard them against those hostile influences in nature which are constantly seeking to destroy them, and which do destroy them in such large numbers.

But though so feeble a power in a direct conflict, Life has other attributes which insure its ultimate and permanent dominion. It has a tenacity, a perseverance, and a fruitfulness, which are never exhausted. It may be overwhelmed, but not annihilated. If an inundation overspread a large district and carry away its soil or overlay it with mud, the waters hardly subside before plants are sprouting and worms are crawling over its surface. If a volcano destroy a fruitful region by pouring over it a flood of lava, a few years only elapse before it it is converted into a fertile soil, and covered again with a new growth of vegetables and a new race of animals. If a forest is burned down, a new one springs up out of its ashes, inhabited, as it was before, by animals of every kind. The surface of the most barren rocks is clothed with mosses and lichens, and in every cranny and crevice plants strike their roots and insects lay their eggs. Flowers bloom on the edge of perpetual snow, and flies buzz in the sun's rays that are reflected from the surface of the glacier. Trees bathe their roots, and fishes and reptiles swim, in the waters of hot springs. Whilst man, the most frail of animals in an open contest with the elements, by providing himself with means of protection of his own devising, becomes the most enduring; crawls into an oven where the heat is that of boiling water, and passes a winter in an atmosphere where mercury is a permanent solid.

It is worthy of remark, that the changes in the condition of the earth which have taken place in these two eras, have not been brought about so much by the agency of great causes as by the accumulated influence of small ones. In the first era, notwithstanding the occasional indications of such events as earthquakes, volcanoes, inundations, the subsidence of water, and the elevation of land, the principal work of direct preparation for the introduction of life seems to have been performed by alternate heat and cold, and snow and rain, which disintegrated and decomposed the rocks, and washed down the materials for soil into the valleys and upon the plains. And in the second, after the appearance of life, it was not by the larger plants and animals that the work was carried on and subsequent changes were wrought, but by the humble, the insignificant, the microscopic, as in the formation of the beds of the Infusoria, and the reefs and islands of the Polypes. The large trees and animals are the products of an advanced period. They are nobler works, but they have not those powers of resistance and that tenacity of life, which qualify them for being pioneers. They appear late in the order of creation, and yet precede for an unknown period that event in which the second era terminates and the third begins, — the introduction of Man upon the stage.

Man, considered merely as an animal, completes the series of living beings. He has all that Life can bestow. It culminates in him. He has instincts and an intelligence more exalted than those of other animals, but still of the same nature. Raise all the capacities which he has in common with them to their highest conceivable power, and he is only the most perfect animal. But, according to the view presented in the last chapter, he is also endowed with capacities specifically different from any which they possess, and these render him capable of entertaining motives for action of which they can form no conception. It is the presence in creation of a being with these endowments, that constitutes the peculiar feature of the third era. The perfect work of animal Life was finished, but man had not become "A LIVING SOUL." A spiritual nature is now induced upon the vital, as the vital was induced upon the material. There is not a more essential difference between the powers which govern creation before and after the introduction of Life, than there is before and after the introduction of this new principle. It is not a difference of degree, but of kind. The most highly developed of animals can have no more conception of this new nature in Man, than a gas or a crystal can have of the nature of a plant or animal.

But, vast as the difference is between the organic and the inorganic, the latter is necessary to the former. The organic can exist only by means of the inorganic. The one is founded upon, and implanted in the midst of, the other. The organic can only exist by entering upon a field which the inorganic has already prepared. The case is precisely parallel in this new creation. Vast as the difference is between the spiritual nature and the animal nature, the latter is as necessary to the former as inorganic matter is to life. This new and higher nature of man can only be implanted and developed in the midst of the varied nature of the animal. We have seen that the living principle secures its place and maintains its ground only by a long and laborious contest against antagonistic influences. In the same way this new principle enters upon a contest with the elements in the midst of which it is implanted, which are necessary to its growth and development, and yet whose tendency constantly is to counteract and expel it. As an immeasurable and inconceivable period of time was occupied in the conflict between life and matter, so, too, we have reason to expect a similar duration of the conflict between the old life and the new; but the plan of Providence, though not uniformly progressive, will in the end be carried out.

Of this plan, progress from the lower to the higher, and to the higher through a preparation by means of the lower, is the essential feature. Yet there is nothing in this work of preliminary preparation which at all indicates the character of that to which it leads. We see no promise of the wonders of organization in the countless combinations of the elements of inorganic matter; nor is there any foreshadowing of that mysterious creation, the human soul, in the varied endowments of merely animal life. Could we conceive of a modern philosopher, who had possessed himself thoroughly of the laws of inorganic matter by a study of them only in the first era of creation, contemplating the state of things which it exhibits, would he not pronounce the existence of such an organism as a plant or an animal to be incompatible with the known course of nature, — an infringement upon its infallible and inevitable laws? And, by those who limit their investigations to the phenomena of inorganic and organic matter alone, is not a corresponding judgment pronounced now? But, as the new law of the life of the animal was introduced at the close of the first era of creation, so the new law of the life of the soul was introduced at the close of the second. In each case there has been inaugurated a new principle of existence, more excellent than that which went before. As the lowest organized being is immeasurably superior to the highest unorganized, — an animalcule to a diamond, — so, too, the lowest man is superior to the highest brute.

What the circumstances were which determined the precise period for the successive introduction of these new elements, we can only conjecture. As already intimated, life probably began as soon as the changes worked out by inorganic laws had established such a soil, such an atmosphere, and such a temperature, as rendered the earth a fit residence for living things. Probably, too, the higher principle was imparted as soon as there had been introduced among the elements of the animal character such a subordination of one to another, such a harmony and relation among them, as rendered it possible for that principle to take root. It is not impossible that man may have existed as a mere animal, and gone through a course of discipline and preparation, long before the inspiration of his divine nature took place. In favor of such a supposition is the accumulating evidence that he has been an inhabitant of the earth for an indefinite period before that epoch which tradition, history, and Revelation have alike assigned for his appearance. But however this may be, his true creation as Man, can only be dated from that moment when was first revealed to him, or when he was first endowed with, that super-animal principle from which flows all that is distinctive in his character. Without this principle, and without the perception of the moral and divine law which proceeds from it, he might have remained for ever of the same nature as the beasts that are made like him, and have been superior to them only in a higher development of the same faculties as theirs.

In the successive stages of this work of creation may be traced the gradual exhibition of those essential attributes of Deity, — Power, Wisdom, and Goodness, — which, although they exist in infinity and eternity, are, to our humble conception, developed only in space and time. In the first stage there are only evidences of Power. The phenomena of this era, when the results to which they lead are not realized, seem like the blind strife of antagonistic forces, tending to no end, indicating no purpose, — the efforts of immense, undirected Power. In the second, there is still Power, but power directed to a definite purpose; for life and organization imply intelligence, design, adaptation of means to ends. Infinite Power, and Infinite Wisdom directing it, are the characteristics of this era. But in it the Universe has no Moral character. Good and Evil, Right and Wrong, have no place in it, and no name. Each individual is a solitary self, controlled only by his own appetites and his own passions, except so far as there exist certain instinctive relations to others, which are necessary to the continuance and immediate welfare of the race. No infinite continuance of mere animal existence could have ever raised it above its original condition.

In the third stage, with the new principle which enters into activity, a new scene begins. Feeble and imperfect in its first efforts, and striving at disadvantage with the principles that preceded it, it slowly penetrates and implants itself among them. Good and Evil, Right and Wrong, are recognized as positive attributes of actions and character. Happiness and Misery take the place of Pleasure and Pain. Before, the individual had no idea but of the good of self, as the spring and motive of action; now, of the good of another. Before, was the reign of self-indulgence; now begins that of self-control. Before, there was no conception but of life in the present; now, not only a conception of life in the future, but of the relation of the present to that future. It may seem idle to claim that the Deity has interfered with the course of nature, so called, by the introduction of a new principle, when we are obliged to acknowledge the feebleness of its influence over the beings to which it has been imparted. We may distrust its paramount strength, we may feel doubt of its ultimate predominance. But how impatient is Man; how patient is Providence! Do we forget how Life struggled, as it were, against Death for uncounted centuries, and yet in the end established its dominion? In this triumph is contained a divine promise that this last contest, though it may seem as unequal, and be as protracted, will in the end accomplish as complete a victory.

It is only when we can thus contemplate the whole series of events in which creation consists, that we attain to a conception of the crowning attribute of Deity, — his Goodness; — his Goodness inspiring his Wisdom; his Wisdom directing his Power. Yet, when we look back from the end to the beginning, and consider, with our present light, the connection of the beginning with the end, we clearly perceive how his attributes have been all concerned, and how they have all coöperated from the first in the accomplishment of one great scheme. It is in the light only of such reflections, that we truly conceive of the great Author of the Nature we have studied, as at once the Creator, the Governor, and the Father of his creatures.

Such considerations may perhaps be deemed foreign to the purposes of this work, and lying out of the limits of Philosophy and Science. Yet, if we believe, nay if we only hope, that the nature and destiny of man are different from that of the animals he so much resembles; surely no considerations which may lead him to a better understanding of that nature and destiny, should be otherwise than of the highest interest. No relation certainly is of so much importance to Man, as that which he bears to the Infinite and the Eternal; and that Philosophy and that Science which regard it as a subject unworthy of their attention, and hesitate to throw all the light upon it in their power, fail in the highest of their duties. There are no subjects toward which the thoughts of mankind are more constantly and eagerly directed, than those which are connected with this great relation; and all knowledge which can bear upon it, and is not made to do so, is like those rivers which, instead of flowing on to the sea, become stagnant in unwholesome swamps, or lose themselves in barren sands.

It is impossible to close our eyes to the fact, that the prevalent tendency of modern science is to put aside, as out of its sphere, all those views of Nature which recognize any direct and continued personal connection of the Deity with his works. Occupied in the earnest but exclusive study of phenomena, and their reference to the immediate laws by which they are regulated, it is reluctant to admit, as a legitimate object of inquiry, any relation those laws may have to the will of a universal, conscious, personal, moral Intelligence. The idea of Deity to which this tendency in Science must finally lead us, is precisely analogous to that of the unconscious though intelligent instinct which presides over the organic, or vegetable, functions of life. It represents Him, therefore, as a being inferior to Man in the kind of his attributes, though superior to him in their degree and intensity, — since Man, beside this instinct, is possessed also of consciousness, will, active intelligence, and a sense of moral relations. That this is now the actual, if not always the avowed, condition of the scientific mind, who can doubt that perceives its all but universal indisposition to admit of any such interference in the affairs of the universe, subsequent to its first creation, as is implied in a Revelation of religion attested by the exercise of supernatural powers, or rather by powers which, so far as we at present understand the constitution and course of nature, we cannot detect as influencing its ordinary phenomena.

It has been the constant object of the work now brought to a conclusion, to present all those subjects of which it treats in such a light as will serve, as far as possible, to counteract this tendency. Should it be found, in any degree, to have this effect, it can answer no more important end.

QUESTIONS.

TO THE TEACHER.

For the sake of brevity in the following Questions, the point is sometimes expressed in a single word, leaving the full form to be supplied by the teacher.

In the study of the Introduction, it will be found of much service to a class, to require a written analysis of each section, upon paper, or upon the black-board, until they are perfectly familiar with the entire classification of the animal kingdom, and are able to write it readily from memory.

QUESTIONS.

INTRODUCTION.

CHAPTER I.

GENERAL CHARACTERISTICS OF LIVING BODIES.

(p. 1) What does *Natural History* in its largest sense embrace? (p. 2.) What is the *Philosophy* of Natural History? What is the purpose of the present work? What is the common idea of the distinction between living bodies and those not living, and between plants and animals? (p. 3.) What is said of the character of living bodies? What is the effect of death on the body? What is the bond which connects its elements? What is the influence of the Principle of Life? (p. 4.) What follows when we are deprived of it? What is the effect of our familiarity with life? What is the influence of the laws of the material world? (p. 5.) What is the relation of the animal to them? Why is a variety of animal forms necessary? Is there a similar variety in the operations of life? (p. 6.) Into what two classes are the objects of the material world divided? What is the first distinction between them? How are living bodies contrasted with the not living? How are they brought into existence? (p. 7.) What is the relation of sex? What is the second distinction? What is Nutrition? (p. 8.) Anything like it in minerals? What is the third distinction? What is meant by *insulation*? How is it illustrated? (p. 9.) What degree of heat and cold can be endured by men and animals?—Give instances. (p. 10.) Any other illustration of insulation? What is the fourth distinction? What is the effect of death? (p. 11.) What is the fifth distinction? What is said of habit?—(p. 12.) Of sleep and torpidity?

CHAPTER II.

CHARACTERISTICS OF ANIMALS AS DISTINGUISHED FROM PLANTS.

(p. 12.) Is there any single essential principle of distinction between plants and animals? What was Buffon's opinion? (p. 13.) Is there any real distinction? State the opinion of Buffon and the objections to it. What is the relation between the functions of animal and of vegetable life, and their respective mode of performance? (p. 14.) Give an account of the seed and the egg, and their development. (p. 15.) What difference is there in the manner in which plants and animals take food?—In the nature of their food?—In their chemical composition?—(p. 16.) In their relation to the atmosphere?—In their circulation?—In the permanence of their organs?—In their nutrition and growth? (p. 17.) What is the final cause of this? What is the result as to their comparative duration and growth? (p. 18.) What powers, in addition to those of plants, do animals possess? What are sensation and voluntary motion? Are there exceptions to the exclusive possession of these powers by animals? Describe them and mention examples. (p. 19.) What phenomena of the same nature are observed in the growth, motions, and sleep of plants? (p. 20.) What is the probable distinction between these motions and those of animals? What is the sensorial power?

CHAPTER III.

GENERAL STRUCTURE OF ANIMALS.

(p. 21.) In what sense is man the most perfect of animals? On what does his distinctive character depend? What are the organic and animal functions? What constitutes the form of man? What is its basis? How are the bones divided? Describe those of the head and face. (p. 22.) Of the back-bone. What is a vertebra? How many vertebræ, and how divided? What are the cavities of the body, and how formed? (p. 24.) What are the extremities? How are the bones united? How are the bones covered? What are muscles and their use? How are they connected with the bones?

(p. 25.) What do the cavities contain? Describe the brain and nerves, and their office.—Effect of the injury or obstruction of a nerve.—Senses in man compared with other animals.—(p. 27.) Digestion, its mode of performance, and by what organs.—Gastric juice and chyme.—Bile and pancreatic juice.—(p. 28.) Chyle and its absorption.—Its entrance into the blood.—Its change from white to red.

(p. 29.) Give an account of the course of the blood. What is the heart? How is it divided into parts and cavities? Give their names. Which side receives the blood from the body? Where does it send it? Where is the blood from the lungs sent? Which side of the heart sends the blood to the body? Shape and position of the heart. Its apex. Which way does it incline? Why supposed to be on the left side? (p. 30.) What is its main body composed of? What are the auricles? Where does the blood receive the chyle? With what other veins does the subclavian unite on its way to the right auricle? Where does the blood from the upper and lower parts of the body unite on the way to the lungs? What are the two great veins which carry it called? Into what cavity of the heart do they pour it? When the cavity contracts where does it send the blood? What prevents it from flowing back? Where is the blood sent by the right ventricle and through what vessel? What is the color of the blood in the right side of the heart? Structure and extent of the lungs. Distribution of the blood through them. Change it undergoes in them, and by what agent. Where conveyed from the lungs and how. (p. 31.) Why is the left ventricle more powerful than the right? By what artery is the blood sent to the body, and what is its name, course, and distribution? What are the capillaries? What becomes of the blood after passing through them? What is the course of the veins? Change in the blood in the capillaries.—Its cause. What is Nutrition?—Absorption?—Excretion?

CHAPTER IV.

STRUCTURE OF ANIMALS AS COMPARED WITH THAT OF MAN.

(p. 32.) Recapitulate the functions by which the life of man is maintained. Are they the same in animals? Why is a variation in them necessary? (p. 33.) Why as to internal as well as external structure? What illustration is given of this necessity? What differences are necessary between man and the monkey? (p. 34.) How is this illustrated? How is a variety of animals necessary to the population of the earth? (p. 35.) What is the final cause of this?

What is the correspondence between the structure of animals and their mode of life? What important circumstance of external condition is taken as an illustration? What are the organs of respiration respectively in animals that breathe air and water?—The difference of circulation in them?—(p. 36.) Consequences of this difference in the organs? State the relation between muscular power and amount of respiration.—In Birds and Insects.—In Fishes and Reptiles. What modification is rendered necessary in the digestive organs? (p. 37.) Similar relations as to other functions. What great naturalist has illustrated this law? State his general principle as to the correspondence between structure and function.—Its application to the digestive organs.—(p. 38.) Relation between the structure of the stomach and that of other organs.—In the jaws.—In the neck and vertebræ.—In the teeth and their sockets.—In the bones, muscles, and joints of the upper extremities.—(p. 39.) In those of the lower, and in the organs of sense.—General application of the principle in the determination of extinct species. (p. 40.) Is there the same strictness as to parts of secondary importance? How is it in the dog?

What use is made of this principle in classification? What is a system of classification? — Divisions universally recognized? — What is a species? — A variety? — Give examples. What is a genus? (p. 41.) What do the animals of the Cat-kind constitute? What are the individuals, as tiger, leopard, &c.? Is the wolf a species or a genus? Of what genus? The squirrel? How do naturalists designate animals? What is the first name? — The second? How do they correspond to the names of men? Examples in the names of animals. (p. 42.) What are the views of Agassiz?

CHAPTER V.

GENERAL SUBDIVISIONS OF THE ANIMAL KINGDOM.

(p. 43.) In how many grand divisions, or branches, are animals arranged? What are they? What other divisions are made? What are the characteristics of the first branch, or Vertebrata? — (p. 44.) Of the second, or Articulata? — Of the third, or Mollusca? — (p. 45.) Of the fourth, or Radiata?

CHAPTER VI.

FIRST BRANCH OF THE ANIMAL KINGDOM. — VERTEBRATA.

(p. 46.) What are the classes of the Vertebrata? What is the distinction between the warm-blooded and the cold-blooded classes? What between the two classes of warm-blooded? (p. 47.) Between the two classes of cold-blooded?

SECTION I.

Class I. Mammalia.

How do monkeys differ from man? — The carnivorous and gnawing animals? (p. 48.) Characteristics of their structure. (p. 49.) What are the variations of structure in the complete quadrupeds? (p. 50.) With what are these connected? Are they equally complete in all? How is the structure varied in the bat? (p. 51.) Could wings be adapted to man? What Mammalia are there which inhabit the water? Describe the Amphibia. (p. 52.) Describe the Cetacea. — How do they differ from Fishes? What peculiarity is characteristic of the camelopard? (p. 53.) For what is it intended? What in the kangaroo? — In the lion, horse, and bull? (p. 54.) What objects are accomplished by the comparative structure of these animals? What are the peculiarities in the formation of the camel, giraffe, elephant, and mastodon, and their purposes? (p. 55.) Can we perceive the object of all variations of structure? Does this afford reason for believing they are without purpose? Why not? In what functions and parts are variations chiefly found?

On what considerations is the division of the Mammalia into orders founded? (p. 56.) How many kinds of teeth have they? What are the orders of the Mammalia, and what are the characteristics of each?

(p. 57.) *What is the first order of Mammalia?* What opinion has been sometimes entertained of the nature of man? (p. 58.) What animals does he most resemble? By what is man distinguished from other Mammalia? How do his hands and feet differ from those of monkeys? (p. 59.) What other differences are there? On what does man's superiority depend? In what is he inferior by nature?

How many distinct races of men? Are the causes of this distinction known? What points of structure distinguish the Caucasian variety? (p. 60.) Why called so? What nations does it include? What is there remarkable in their character? What are the marks of the Mongolian variety? What have been their history and character? (p. 61.) What are the marks of the African variety? What their history and character? What distinguishes the American variety? What nations belong to it? What distinguishes the Malay variety? What nations belong to it? (p. 62.) What division of races does Mr. Pickering propose? What are the sources of man's superiority to other animals? (p. 63.) To what is his progress owing as compared with them? What is his primitive condition? (p. 64.) By what means does he emerge from it, and what are the causes of his improvement?

What is the second order of Mammalia? How do the Quadrumana differ from man? (p. 65.) For what kind of motion does their structure especially fit them? What are the different kinds? What is a prehensile tail, and where are those found that possess it? Where is the Orang-outang found? — Describe him. — (p. 66.) The Chimpanzee. — The Gorilla. What are the Howler monkeys?

(p. 67.) *What is the third order of Mammalia?* — Its characteristics? What is the first tribe or family? — (p. 68.) Describe them. — The Vampyre. — The Spectre Bat. What is the second tribe? — Its characteristics? Describe the Hedge-hog. — (p. 69.) The Mole. What is the third tribe? — Their characteristics? Are they all exclusively carnivorous? Mention some of the principal kinds, and their peculiarities. (p. 70.) Describe the Dog. — The animals of the Cat-kind. — The Lion. — (p. 71.) The Tiger. What is the fourth tribe? How do the Amphibia differ from other quadrupeds? — Seals.

(p. 72.) *What is the fourth order of Mammalia?* — Its characteristics? What is the peculiarity of the teeth of the Rodentia? Describe the Beaver. — (p. 73.) The Jerboa. — The Canadian Jerboa. — The Hamster. — (p. 74.) The Louisiana Marmot. — The Porcupine.

What is the fifth order? — Origin of their name? — Characteristics? Describe the Three-toed Sloth. — (p. 75.) Armadillo. — Ant-eater.

What is the sixth order? (p. 76.) What are its characteristics? What is rumination? How many stomachs have the ruminants? — Their names? (p. 77.) What is the value of the ruminants to man? Describe the Camel and Dromedary. — (p. 78.) The Llama. — The American Bison. — The Camelopard, or Giraffe. Which of the ruminants are destitute of horns?

What is the seventh order? (p. 79.) Why called Pachydermata? Describe the Elephant. — Its tusks. — Its trunk. — How many species of it? — The Mastodon. — (p. 80.) The Hippopotamus. — The Rhinoceros. — The Tapir. — The Wild Boar. (p. 81.) What are the Solipeda? Name the several species. — Their character and mode of life.

(p. 82.) *What is the eighth order?* How do whales differ from fishes? Describe the herbivorous Cetacea. (p. 83.) What are the blowers? Describe the great Greenland Whale. — (p. 84.) The Spermaceti Whales. — What is ambergris?

What is the ninth order? The original distribution of the Marsupialia and Monotremeta. — Chief characteristic of the Marsupials? — (p. 85.) Of the female. Describe the Opossum. — The Phalangers. — The Flying Opossum. (p. 86.) The Merian Opossum. — The Kangaroo.

What is the tenth order? What is the most remarkable species? Describe the Ornithorhyncus. — The Echidna.

SECTION II.

Class II. Birds.

(p. 87.) What is the reason of the uniformity of structure in Birds? What is the peculiarity in the locomotion of Birds, and how does it influence their structure? (p. 88.) What is the connection between their locomotion and the extent of their respiration? What peculiarity is there in their bones? — And what advantage from it? — (p. 89.) And from the construction of their skeleton? What nice adjustment is necessary in the act of flying? How is the equilibrium preserved? (p. 90.) How does the bird maintain its posture as a biped? How does it differ from that of man? (p. 91.) How does it maintain its position in sleep? What are the structure and relative proportions of the head and neck? Compare the body of a bird with that of a quadruped. (p. 92.) How is the economy of muscular power in the bird shown in its posture? — In the size of its foot? (p. 93.) What are the circumstances which make the structure and motions of birds so remarkable? What is the covering of birds, and its adaptation to their functions?

(p. 94.) On what points is the scientific arrangement of Birds founded? How many orders? *What is the first order?* — Its characteristics? Describe the diurnal Accipitres. — The nocturnal. (p. 95.) *What is the* *second order?* — Its characteristics? What birds are included under the Passeres? (p. 96.) Describe the Bird of Paradise and the Humming Bird. *What is the third order?* — Its characteristics? (p. 97.) What birds are included under the Scansores? Describe the Woodpecker. — The Toucan. *What is the fourth order?* What birds are included under it? — Their characteristics? (p. 98.) In what do Pigeons differ from the other Gallinaceæ? — The Crowned Pigeon. *What is the fifth order?* How are the Grallæ distinguished? What birds are included? (p. 99.) The Ostrich and Cassowary. *What is the sixth order?* How are the Anseres distinguished? What birds are included?

(p. 100.) Describe some of the peculiarities of the Accipitres as contrasted with the Grallæ. (p. 101.) How are the Grallæ enabled to stand long without great strength of limb? How is it with the Ostrich? What orders does the Ostrich form a link between? What is the division of power in the Passeres and Scansores? In the Anseres, or Palmipedes? (p. 102.) What is there peculiar in Guillemots and Auks?

SECTION III.

Class III. Reptiles.

What is the third class of vertebral animals? What animals does the class of Reptiles include? (p. 103.) How are their circulation and respiration performed? What is the effect of this on their blood and heat? — On their general habits of life? (p. 104.) How many orders? How is *the first order,* the Chelonia, distinguished? — The carapace. — The plastron. — Of what are these composed? What animals belong to this order? *The second order?* What animals are included in the Sauria? Describe the Crocodile. — (p. 105.) The Dragon. — The Chameleon. (p. 106.) *The third order?* How distinguished? How are the Ophidia divided? Describe those not venomous. Describe the venomous. — Their fangs. — The Rattlesnake. — (p. 107.) *The fourth order?* How do the heart and circulation of the Batrachia differ from those of other orders? For what are they principally remarkable? Describe their transformations. Are these complete in all? — The Lepidosiren.

SECTION IV.

Class IV. Fishes.

(p. 108.) What is the relation which the several classes of Vertebrata bear to the medium in which they live? — The difference between Birds and Fishes? (p. 109.) What is the effect of this on their structure, especially as to the muscular system, respiration, and circulation? Describe the gills. — Mode in which respiration is performed by them. Does the skeleton differ from that of the other classes? (p. 110.) To what do the fins correspond ? — Their office ? What is the air-bag ? — Its contents ? — (p. 111.) Its supposed office ? — Objections ? — Its probable purpose ? — (p. 112.) Its connection with respiration ? Describe their covering. — Teeth. — Means of defence. — Their brain and senses. — Skeleton. — Digestive organs. — Food. — Their division into orders.

CHAPTER VII.

SECOND BRANCH OF THE ANIMAL KINGDOM. ARTICULATA.

(p. 113.) What is the most interesting class ? Describe the characters of Insects. (p. 114.) What is their substitute for a skeleton ? Are all winged ? (p. 115.) How are their bodies divided ? Describe the head. — Any brain ? — Their senses. Describe their mouth, jaws, and mode of feeding. — Their extremities and wings. — Number of legs. (p. 116.) Number and structure of wings. — The balancers. Describe the abdomen. — How is it sometimes terminated ? What are their metamorphoses ? (p. 117.) Give an account of that of the Butterfly. — The larva. — The chrysalis. — The perfect state. What useful purposes do Insects serve ? (p. 118.) Into how many orders does Linnæus divide Insects ? And on what does he found the division ? Name *the first order,* and its character, with examples. *The second order,* and its character, with examples. (p. 119.) *The third order,* — character, — examples. *The fourth order,* — character, — examples. (p. 120.) *The fifth order,* — character, — examples. What is said of the Ant, Wasp, and Bee ? (p. 121.) *The sixth order,* — character, — examples. *The seventh order,* — character. — What are included under the Aptera ? (p. 122.) The Spider. Habitations and habits of spiders, — The Tarantula and Scorpion. (p. 123.) What is said of the Crustacea ? Describe the principal points of their structure. (p. 124.) How are they covered ? How do they change their shells ? Describe their claws. — Organs of sense. What is there peculiar in their stomach ? (p. 125.) How is the term *Worm* used ? What are the Annelida ? — Their nervous system ? — Their blood, circulation, and respiration ? — Limbs ? — Mouths ? — Bodies ? — Habitations ? — (p. 126.) The Earth-worm ? — The Leech ? — The Gordius ?

CHAPTER VIII.

THIRD BRANCH OF THE ANIMAL KINGDOM. MOLLUSCA.

(p. 127.) What are included ? — Examples. Give a general description of their structure. What is the mantle ? How is it arranged ? (p. 128.)

Describe their shells. — Any brain ? — Their nervous system. — Respiration and circulation. — Heart and blood. — Their organs of digestion. (p. 129.) How are the Mollusca divided into classes ? Describe those of the first class. What peculiarity have some of them ? What is said of the size of some of them ? (p. 130.) Describe the Mollusca of another class. Examples. Describe another class. — Examples. — The common Clam. — (p. 131.) The Giant Clam. — What is the organ called the foot ? How are the shells of the bivalve Mollusca connected ?

CHAPTER IX.

FOURTH BRANCH OF THE ANIMAL KINGDOM. RADIATA.

What animals are included under this branch ? (p. 132.) What were they formerly called ? Give a general account of their structure. Are there any exceptions ? What are they ? What are the organs of motion in the Echinodermata ? Describe the Starfish. — (p. 133.) The Sea-nettles or Sea-anemones. — The Medusæ. — The Polypes. — (p. 134.) The Animalcules, or Infusoria. (p. 135.) What is a peculiarity in the structure of some of the Infusoria ? What facts are there concerning their minuteness, immense numbers, and prolific nature ? (p. 136.) How does the view of the animal creation illustrate the attributes of its Creator ?

PHILOSOPHY OF NATURAL HISTORY.

CHAPTER I.

FOOD, DIGESTION, AND BLOOD OF ANIMALS.

(p. 137.) What is said of the correspondence between the organs of digestion and the form of animals? — And of man and other animals below him, in regard to their food, organs of digestion, and other organs? (p. 138.) What is said of the natural food of man as compared with that of other animals? Mention the food of various races. What relation do health and strength bear to the kind of food? (p. 139.) What is the effect of heat on food? Is there any essential difference in kinds of food?

What is said of the natural food of man? — (p. 140.) Of his food in different climates and under different circumstances? — Of it in Africa? — Of the consumption of fat in cold climates? Mention some examples. (p. 141.) Any connection between kinds of food and powers of motion? (p. 142.) What is the best food for man? — Any exceptions? How is man determined in his choice of food? Mention some examples. Describe a strange kind of food which is sometimes resorted to. (p. 143.) To what is its nutrient power attributed? Cases mentioned by Dr. Livingstone. What is the effect of a very exclusive diet? — Examples. (p. 144.) To what is owing man's power of accommodating himself to different residences? What effect has the want of this on animals? How are these facts connected with the distribution of animals over the earth? What is the relation of animals to plants and to each other as food? (p. 145.) How is the suffering from this relation mitigated? Examples which illustrate this. (p. 146.) Mention a statement of Dr. Livingstone.

How is man directed in his choice of food? How are animals? Are their tastes uniform in this respect? (p. 147.) Have they a power of accommodating themselves to unnatural food? What limits to this? Examples. What is idiosyncrasy? Examples of it. (p. 148.) Relate an instance from Réaumur of adaptation of food to particular species.

(p. 149.) On what has the digestion of food been supposed to depend? To what is it probably due? On what kinds of stomach did Spallanzani experiment? Describe the results of his experiments upon birds with strong gizzards, when perforated metallic balls were used, with grain unbruised, — (p. 150,) with grain bruised, — with tin tubes, — with pieces of glass, —

with strong tin needles, — with lancets. (p. 151.) What was his opinion of the stones found in the gizzards of birds? Is it well founded? Describe his results on stomachs of an intermediate kind, with tubes of tin and lead, — with unbroken grain and seeds, — with the same bruised. (p. 152.) What was the result of his experiments on membranous stomachs? Describe Dr. Stevens's experiments on the action of the human stomach on raw flesh, — on boiled — on chewed meat, (p. 153,) on vegetables. — His experiments on dogs and ruminating animals. What inference does he draw as to the natural food of man? (p. 154, note.) How far is this opinion correct? State the results of Dr. Beaumont on digestion. What effect does the stomach produce upon living animals? Mr. Hunter's remark. (p. 155.) Why does not the stomach digest itself? Why does it digest itself after death?

What is the ultimate purpose of digestion? What is the appearance, &c., of the blood? (p. 156.) What changes take place in the blood when out of the blood-vessels? Describe the serum. — The crassamentum. — The red globules. — Their diameter in man. — In other animals. (p. 157.) How are the different organs formed from the blood? — How the fluids? What are the constituent parts of the blood called? What are its ultimate elements? What is their relation to the proximate? Is any one of the proximate elements really more essential than another? (p. 158.) Where are the proximate elements manufactured? What article is a type of food? What does milk contain? How does it compare with other aliments? What are condiments, and their use? (p. 159.) What is the relation of common salt to food? What circumstances determine the proper quantity of food? What is the relative growth at different ages? — In the lower animals?

CHAPTER II.

CIRCULATION AND RESPIRATION.

(p. 160.) What was stated of the circulation in the Introduction? What is the time occupied by the circulation? Describe the mode in which the blood flows through the arteries and veins. What peculiarity is there in the mode in which the arteries pass along the limbs?

(p. 161.) Why do they pass on the inside of the limbs? What effect from arrest of circulation? What else is necessary as to the blood? Why is the heart a particular subject of admiration? (p. 162.) What natural objects are especially indicative of creative design? How is this accounted for? Why nothing singular in this?

(p. 163.) What effect has respiration? What is the air? What is its composition? On which element does it chiefly depend for its vitalizing influence? (p. 164.) How necessary is air to life? On what does its necessity depend? In what does the change consist in red-blooded animals? How is respiration performed in the Mammalia? How long may it be suspended? What is the fact with regard to pearl-divers? Will any air but atmospheric support life? How do water and some gases destroy life?

(p. 165.) How much air do the lungs contain when full? How much is drawn in and expelled at each respiration? What change takes place in the air? What connection is there between respiration and animal heat? What is the explanation of its production? Is this probably the only cause? (p. 166.) Is there any variation in the proportion of oxygen? On what does the healthiness of different regions depend? What change takes place at birth? What is the connection between the action of the heart and lungs? What is the effect, if their functions cease?

(p. 167.) What other purposes has respiration? How is communication between animals effected? How is speech performed? On what does dumbness depend? How is laughing performed? — (p. 168.) How weeping? — Are they common to animals? How do animals express pleasure, pain, and other emotions?

Describe the respiration of Birds. (p. 169.) What purposes does this provision answer? Its connection with their lightness, motions, and consumption of air. What is said of the voice of birds? Where and how is voice produced in Mammalia and in them? (p. 170.) On what do its variations depend? What else is stated of voice?

What is the structure of the lungs in Reptiles? — And their mode of respiration? — Their endurance of its suspension? (p. 171.) What is their temperature? — Their power of enduring heat and cold?

How is the respiration of Fishes carried on? — Through what medium? If they are deprived of air, what is the effect? (p. 172.) Describe an experiment with the air-pump on carp.

How is air supplied to Insects? (p. 173.) Give an account of Réaumur's observations on rat-tailed worms. Describe the structure of the tail. Transformation of the worms. (p. 174.) Describe the respiration of another species of worm. State the provision for the supply of air to animals in various stages of transformation, *e. g.* the rat-tailed worm in the chrysalis state — (p. 175,) — the dragon-fly — the ephemeron fly. — (p. 176.) Opinions of Clutius and Réaumur.

How do Crustacea, Worms, and Mollusca respire? — How the Radiata?

CHAPTER III.

CONNECTION OF ANIMALS WITH HEAT, LIGHT, AND ELECTRICITY.

(p. 177.) How extensive is the power of maintaining an independent temperature? How is it in the lower animals? — In Reptiles? — In Insects ? — In bees ? — (p. 178.) — In the common caterpillar ? What connection has it with the health — when is it least vigorous ? What is said of hardening children ? (p. 179.) What variations are there in the heat-making power ? What is said with regard to effects of exposure on health ? When are diseases from cold most prevalent ? When is the heat-making power at its minimum ? — Its maximum ? What inferences are drawn as to clothing and artificial heat ?

(p. 180.) What is said of relations of animals to light ? — Of luminous insects ? Is the cause and mode of its production understood ? What luminous animals are most numerous ? State the remarks in the note. (p. 181.) What is said of the connection of light with health ? Give the anecdote illustrating this connection ? What is the experience of army physicians ? (p. 182.) What is said of light for invalids ?

Is there any connection between electricity and the bodies of animals ? Describe the phenomena presented by electrical fishes. — The organ by which the electricity is developed. How have these animals been captured ? (p. 183.) Under what conditions is the shock communicated ? Does this power exist in any other animals, and what are they ? Under what circumstances has electricity been developed in the animal body. Describe the phenomena. (p. 184.) What is the connection of the weather with them ? What effects are produced on the human frame ? — On the character of winds and weather ? — On animals ?

CHAPTER IV.

MOTIONS OF ANIMALS.

(p. 185.) How many distinct kinds of motion are there by which the functions are performed ? — Name them and describe them. Which kind are the most complete ? Do voluntary motions ever become involuntary ? Is it always easy to distinguish them ? (p. 186.) By what organs are the motions performed ? What are muscles ? — Their structure ? Is the muscle itself always fixed to the bone ? What is the purpose of a tendon, and how does it operate ? — What example illustrates this ? (p. 187.) How far are the size and shape of parts dependent on muscle ? State the connection between the use of muscles and their development. What is the inherent power of muscle ? How is it called into activity ? — Its natural exciter. (p. 188.) Influence of various circumstances on muscular contraction. What difference between the muscles of the old and the young ? — Practical inference ? What precautions are recommended as to muscular exercise in the young ? (p. 189.) To what motions does nature prompt young animals ? What is said of dancing ?

What different positions are assumed by animals ? — By man ? — What is said of it ? By birds ? (p. 190.) Is standing on four feet easier than on two? State the remarks on certain mechanical provisions in relation to the posture of quadrupeds.

How many modes of progression? Describe them and their difference. Which is the most fatiguing? Describe walking on two feet. (p. 191.) What difference in the young, the old, and the feeble? What assists in keeping the balance? Describe the walk of the horse. — The trot. — (p. 192.) The gallop. — The half gallop. — The pace. — The rack. By which feet is the impulse forward given? (p. 193.) How is this when there is great disparity between the limbs, as in the kangaroo and camelopard? The natural pace of different animals.

What is an essential point of difference between motions on land and in air or water? Describe the rise and flight of Birds. — The effects of different obliquity of the wings. (p. 194.) How do Fishes perform their various motions?

State circumstances relative to the motions, speed, and endurance of various animals. (p. 195.) Compare the motions of small animals with those of large. —Which manifest the greatest power in proportion to size? State what is said of the speed of Birds. — Of the ostrich, — crow, — eider-duck, — hawk, — falcon, — (p. 196,) — canary-bird. Of the motions of Fishes and Whales. Of motion by suction, — in Insects, — in the walrus and seal. — In a species of lizard, — in the remora.

(p. 197.) Describe the various motions of Insects. — Their rapidity and continuance, — how illustrated in a railroad carriage? — Their speed in running. (p. 198.) Their climbing, swimming, and diving, and burrowing. Describe the motions of mussels. — What is their trunk or tongue? — How do they use this in progressive motion?

CHAPTER V.

VOICE OF ANIMALS, AND THEIR MODES OF COMMUNICATION.

(p. 199.) What is the purpose of sounds in Nature? What is proper voice, and to what animals is it confined? — How produced? — On what principle? (p. 200.) State the distinction between voice and articulation. — The difference between vowel and consonant sounds. Of which does the voice of animals chiefly consist? What approach to consonants is there in some? (p. 201.) What indications are there in monkeys of intercommunication by language?

Among which of the invertebral animals are the principal examples of sound? — Point out the distinctions between them as to their object. — Give other examples of insect sounds. (p. 202.) Are there probably other means of communication among them? — State examples of this in ants. (p. 203.) To what organs does Huber attribute this power? How do they use the antennæ in battle? — in their dwellings? —

in the administration of food, &c.? (p. 204.) Have we any distinct conception of these communications? What example is given of the probable production of sounds by shell-fishes? In what cases does the production of sounds by animals imply the sense of hearing? (p. 205.) Is it probable that the power of appreciating sounds is extensively diffused among the lower animals? How far may the prevision of insects depend on an exquisite power of this kind?

CHAPTER VI.

SENSATION IN GENERAL. FEELING AND TOUCH. TASTE. SMELL.

(p. 206.) What is the relation between the wants, appetites, &c., of the animal and his senses? What is the connection between the nature of the guiding principle of the operations of an animal and the need of the senses by which to act? (p. 207.) How many senses may there be?

What is the probable amount of sensation in the lowest Radiata? What change takes place as we ascend the scale of being? Where do smell and taste become entirely distinct from general feeling, and sight and hearing appear? — (p. 208.) Their relation to freedom of motion. — Same relation in Insects. How diffused is the general sense of feeling? In what part does it chiefly reside? How is touch distinguished from it? How is touch exercised, and on what conditions does its nicety depend? (p. 209.) What is its most perfect organ? — What the next? Trace the gradual deterioration of the organs of touch through different animals. What is the relation of the senses to the organs? (p. 210.) What parts have a nice touch in quadrupeds? State the connection of this with their mode of taking food. Describe the nicety of the sense in bats, and how shown. How is this sense in Birds, Reptiles, Fishes, and Insects?

Of what qualities does taste inform us? (p. 211.) Describe its character in different animals. The difference between the pleasure of taste and of taking food. Describe the seat of taste and the manner in which it is produced.

(p. 212.) Describe odors, so far as their nature is understood. — The phenomena attendant on their diffusion. State the distinction between the irritation produced by an odorous body and its proper odor. What is said of the singular and curious character of the phenomena of odor? — (p. 213.) Of the relation of smell and taste to the appetite and choice of food? Where does the smell reside in animals that breathe air? — In those that breathe water?

CHAPTER VII.

HEARING.

(p. 214.) How is sound produced? Is hearing necessary to the perception of its vibrations? How frequent must be the vibrations to constitute sound? On what does pitch depend? Is the transmission of sound confined to air? At what rate does it travel? What causes vary this rate in the air, and how much? (p. 215.) How much is it varied in other bodies? — In carbonic acid gas? — in crown glass? — in other solids and liquids? State an experiment on the rate in cast-iron. State the facts which illustrate the conveyance of minute sounds, and why this takes place better through solid substances than air. — The difficulty with which they pass from one medium to another.

(p. 216.) What is the office of hearing? — Its relation to sight? What difference is there in animals as to the information from this sense? On what does it depend? How much can we teach animals by language? (p. 217.) State the necessity of the modification of the organ of hearing in different animals.

What are the qualities of sound that man can distinguish? Give a general description of the ear. What is the essential part? For what purposes are the secondary parts intended? (p. 218.) What is the difference between the ear of the higher and of the lower animals? Give a particular account of the structure of the ear. — Of the external ear. — Its office. — (p. 219.) Of the tympanum. — Its membrane. — Its function. — Of the small bones. — Of the labyrinth. — (p. 220.) Of the mode in which these parts concur in the production of hearing. — Of the function of the drum analogous to that of the iris of the eye. Are these parts varied in other animals, and why?

On what does distinctness of sound depend? The different qualities of sound in this respect? State Dr. Wollaston's observations on sounds inaudible to certain ears. (p. 221.) How do we judge of the direction of sounds? How are they modified? How does the ventriloquist avail himself of this? Are animals superior to man in judging of direction? Why? How do we judge of distance? (p. 222.) What circumstances influence the apparent distance? What is the effect of habit and education on our judgment? Example. What inference as to sound may be drawn from this? (p. 223.) What interval of sound can we appreciate? What effect has this upon sounds as they reach the ear? — In combining reflections of a sound with the original? What influence do bodies probably produce on the sounds they reflect? (p. 224.) What inferences are drawn from this as to the information that may be derived from sounds? — Example, as to the construction of rooms for music and and public speaking. — As to echoes.

CHAPTER VIII.

SIGHT. EDUCATION OF THE SENSES, AND THEIR COMBINATION AND RECIPROCAL RELATIONS.

(p. 225–6.) What is a camera-obscura? How is an image produced in it? Explain by the diagram its resemblance to the eye. Describe the coats of the eye. Which receives the image of external objects? What is the cornea? — (p. 227.) The crystalline lens? — The aqueous humor? — The vitreous humor? — The iris? — The retina? Describe the office of these parts. — The color of the inside of the eye. Why is it black? How is the eye situated? — How moved? — How protected? (p. 228.) What is the use of the tears? Describe the manner in which they are diffused, &c. What is the use of the eyebrows and eyelashes?

What is the optic axis, and how is vision related to it? Can we see any object except in the line of this axis? What is said of the seat of direct vision? (p. 229.) How long after a sensation does its impression continue? What phenomena are explained by this? Why cannot a moving body be represented? Explain the stationary appearance of a moving body as seen by lightning. What is stated of the point of the retina at which the optic nerve enters? (p. 230.) Describe experiments which illustrate this. Explain the office of the iris. Is it influenced except by light? Explain several phenomena connected with the iris. (p. 231–2.) Is there any other cause for them? Describe the phenomena of accidental colors. Explain the cause of them. What do these facts indicate? — Of what practical application are they capable? (p. 233.) What other phenomena are described? What is said of the insensibility of certain eyes to some colors? Examples.

(p. 234.) What two questions concerning vision have excited controversy? What is said of the first? — Of the second? How great is the range of single vision? What objects appear single? Why do they appear so? What inference is drawn as regards place? Describe an experiment which illustrates this. When does an object appear single? (p. 235.) How does this explain the phenomena of the stereoscope?

What is the effect of education and experience on sight? — Its state at and after birth? (p. 236.) How do we judge of the position of bodies? — Of their perpendicularity? Explain the optical phenomena in a ship at sea. (p. 237.) How do we estimate the distances of near objects? — How of more remote? (p. 238.) What is the effect of vividness and distinctness? — Examples. How are we aided by intervening objects? What renders it difficult to judge of objects not on the same level?

(p. 239.) How is the most simple idea of the motion of a body produced? Do all movements of the image over the retina produce it? — When do they not? Apply this to the explanation of phenomena of railroad carriages.— Of vessels on the water. — Of trees, while moving among them. — Of the heavenly bodies. Explain various cases of apparent motions. (p. 240.) What is the natural relation of the eyes to the will? What is the effect when the control of the will is suspended? Explain dizziness. — The connection of these facts with disease. — With sea-sickness.

(p. 241.) What is the residence of the different senses? — Of the touch? Describe the connection of the face with the organs of sense. What inferences do we draw as to the character of the animal? (p. 242–3.) Describe the orbit, and its direction in different animals. — In man. — In monkeys, and its effect on their expression. —In other Mammalia, Birds, Reptiles, and Fishes. — In whales. — In lizards. What relation is there between the direction of the axes and the character and habits of animals? Does the size of the eye bear any relation to that of the animal? — What indication from a large eye? — Apparent exception in bats.

What is said of the range of distinct vision? — In man and quadrupeds? — (p. 244.) In Birds? — In birds of prey? — Examples. — Is the explanation understood? What modification do the eyes of Fishes require? — (p. 245.) By what change is it effected? What common facts require explanation? What conditions are necessary in order to see clearly from one medium into another? When does vision become indistinct? Apply this principle to the vision of fishes. (p. 246.) Explain the effect, on vision, of ground glass. — Of an uneven surface of water. — Of unequally heated air, and of cold air. What account is given of vision in animals that live both in air and water, as in reptiles and whales?

(p. 247.) What is the office of the third eyelid in birds? — its name? Of the eyelid in fishes? (p. 248.) What is said of the organs of vision in the lower animals? Of the eyes in insects? What is a simple eye? — A compound eye? How many lenses may this have? Why has it so many? (p. 249.) What remark is made of animals lower in the scale?

What is our condition as to the senses in adult life? — In infancy? — In what does their education consist? What are the first impressions on the mind of the infant? (p. 250.) What two senses are principally educated together? How does the child first learn the existence of anything beside himself? — What is the next process? Why is the hearing less rapidly educated than sight? — (p. 251.) What is its ultimate comparative importance? — Its connection with language? After their education, on what senses do we most depend? (p. 252.) What is said of the order in which the senses are educated? What is the exercise of the senses in animals? On what depends the superiority of the senses in man? — (p. 253.) Of the smell in quadrupeds? — What example? What sense predominates in different classes? What unaccountable phenomena are there? What is said of the senses in insects? — Mention an example in bees. (p. 254.) Describe the powers of insects in foreseeing the weather.

CHAPTER IX.

REPRODUCTION AND TRANSFORMATION.

(p. 255.) What is the medium of the transmission of life from one individual to another? What is incubation? State the conditions necessary to it. — What degree of heat is necessary? [Note.] (p. 256.) What is said of the comparative tenacity of life in the eggs of different animals? State Capt. Franklin's remark, &c. What is said of moisture? — (p. 257.) Of air? What inference is drawn from these facts? Describe the instinct of animals as connected with their young. — (p. 258.) Give examples. Effects of the instinct of maternity? — Examples. (p. 259.) Is this instinct unerring. — (p. 260.) How is it in Fishes? — In insects?

(p. 261.) What other modes of reproduction beside that by eggs? What is said of the regeneration of parts? (p. 262.) What is said of the changes which take place during life in man and other animals? — Of the transformation of the frog? — (p. 263.) — Of insects? — (p. 264.) Of other animals? What analogy do these facts bear to some in the higher animals?

CHAPTER X.

DISTRIBUTION OF ANIMALS. — COVERING, MIGRATION, AND HYBERNATION.

(p. 265.) How were animals originally located and distributed? On what circumstances does their distribution depend? (p. 266.) How far are the animals of different regions distinct? What difference between those of the Old World and the New? Any reason for inferring a superiority of the former. (p. 267.) How is it in Australia? How are the unfavorable effects of climate obviated?

What changes take place in the covering of animals. (p. 268.) What in the color of it, and how do these changes serve to protect them from cold and heat? (p. 269.) How is the effect of a black skin in hot climates explained?

What animals chiefly migrate? What varieties in the migration of Birds, and on what do they depend? (p. 270.) Describe the course taken in migration. —What examples are given? — The bobolink, &c. — (p. 271.) Snow-birds, &c. — (p. 272.) The snow-bunting. — The wild goose. — Its probable northern resort. — (p. 273.) The swallow.

(p. 274.) What is a state of Torpidity? What purpose does it answer? What quadrupeds hybernate? — The position taken? (p. 275.) What precautions are taken? What variations in the state of torpidity? The state of respiration, circulation, and animal heat? How are these varied by circumstances? (p. 276.) How does the action of the heart vary? How is the torpid state brought on? How may it be prevented? How does it vary in different animals? — (p. 277.) In the marmot? — Hamster? What is the ultimate purpose of hybernation? (p. 278.) What is the effect of extreme cold? — Object of this provision? In what condition do animals come out of the torpid state? Its connection with the constitution? (p. 279.) Has it any connection with the state into which man falls from extreme cold.

What is said of torpidity among the lower classes? — Reptiles, Fishes, and Insects? — The snail? (p. 280.) What effects have been observed from deprivation of moisture? Describe some examples of imbedded toads and frogs. — (p. 281.) Instance of torpidity in man. (p. 282.) How are animals protected against heat and dryness? What is meant by æstivation? — Give some examples of it.

CHAPTER XI.

HABITATIONS OF ANIMALS.

(p. 283.) What varieties are there in the habitations of animals? Describe those of the Alpine Marmot. — (p. 284–5.) — Of the Beaver. — (p. 286.) Of the Mole. (p. 287.) What is said of the nests of Birds? — Of the rapacious tribes? — Of the Eagle? — (p. 288.) Of the Tailor-bird? — Of the Baya? (p. 289.) Of the Waders? — Of the Republican Grosbeak? — (p. 290.) Of the Bower-bird? — Of the Brush Turkey? — (p. 291.) What are the largest nests ever found?

Describe the nests of the Mason Bee. — (p. 292.) Of two other species of Solitary Bees. (p. 393.) — Describe the construction of the comb and cells of the Honey-Bee. What differences are there in the construction of the cells, and for what purpose? (p. 294.) Describe the manner in which their labors are carried on. By what process is wax produced? — And from what? (p. 295.) What is Huber's account of this process? Describe the manner in which, and the instruments with which, bees work. (p. 296.) What is *propolis?* For what is it used? (p. 297.) How do bees dispose of animals that enter their hives? How do they collect and dispose of honey? (p. 298.) Describe their mode of feeding each other.

Describe the construction of Wasps' nests. — (p. 299.) The material of which they are composed. Where do they build them? Describe their external and internal arrangement. — (p. 300.) The number of cells. — Of young wasps produced. — Mode in which wasps build. (p. 301.) What takes place when a nest is removed into a hive. How do wasps collect materials, and where? (p. 302.) Describe the different kinds of wasps in each community. — Their several occupations, collection and kind of food, and its distribution. (p. 303.) How are the young taken care of and fed? — Their metamorphosis. (p. 304.) For which kind are the first and greatest number of cells prepared? Why is this? What is the duration of the life of Wasps? Which kind survive the winter? Which kind found new communities? The difference between Bees and Wasps in these respects. (p. 305.) What is the occupation of the male wasps? Which of the wasps have stings?

How many sorts of ants are there in the same society? — Describe them. — (p. 306.) What becomes of the males and females? — The office of the neuters? How do different species vary in their habitations? What is their food? Which sort of an ant provides it? — Which takes care of the young? (p. 307.) Give some account of the Termites. What three orders are there of the *termites bellicosi?* (p. 308.) Which is the most numerous? What are they called? Describe the three orders. — Their relative size, &c. Are they really different kinds, or merely transformations of the same insect? In what manner are new families commenced? (p. 309.) What change takes place in the queen? What is the number of her eggs? What are their nests called? (p. 310.) Give an account of one of their villages and of the exterior and interior of their hills. How are they formed? Describe the royal chamber. (p. 311.) How is it surrounded? What are the magazines? — The nurseries and the changes in them? How are these changes effected? What is the situation of the royal chamber? (p. 312.) How do the surrounding apartments appear? What is the construction immediately under the dome? How are the apartments protected from water? What is the size of the subterraneous passages? — The material with which they are constructed? Describe their subterraneous galleries. (p. 313.) Describe what takes place when an attack is made on their dwellings. — The conduct of the soldiers and laborers. — (p. 314.) The office of the sentinel. — The difficulty of exploring their nests.

CHAPTER XII

RELATION OF ANIMALS TO MAN. — THEIR EDUCATION AND DOMESTICATION.

(p. 315.) What is the feeling of animals towards man? What reason is there to believe that many animals have no natural fear of him? (p. 316.) What is Stetter's account? How is it with the ferocious beasts of prey? (p. 317.) With sea-fowl and birds of prey where they are unaccustomed to his presence, as compared with their fear of him when known? — (p. 318.) Mention instances. Is there a difference between the domestication of a species and the education of an individual? Are all the domesticated animals known to have existed in the wild state? What have been their services to man? What substitute has he found for them? (p. 319.) What correspondence is there between the character of the domestic animals in different regions and his wants? Have they probably undergone any change from domestication? How is it with the horse? Are all domesticated animals educated? Which are, and which are not? — (p. 320.) Give some examples of education.

Why has not the education of birds been carried to the same extent? Give some examples of what has been taught them. — Of the crow, — (p. 321,) wild-goose, — buzzard. Give an account of the different steps in the education of the falcon. (p. 322.) What is required in the education of animals? What mode of treatment is most successful? What is said of the appeal to the imitative propensity? In what animals has it the most effect? What are the capacities of monkeys for education? (p. 323.) What have they been taught? What are their imitative powers as compared with those of parrots? Describe the manner in which this propensity has been taken advantage of. — (p. 324.) How it has been ludicrously exhibited. Give an account of what the orang-outang has been taught? How have monkeys been regarded in various countries? (p. 325.) What is said of the combination of the powers of the monkey and the parrot? In what birds does the power of imitating the voice and other sounds mostly exist? Describe the performances of the American mocking-bird. — (p. 326.) Of parrots. What kind of phrases do they most easily learn? Describe a remarkable case of imitation in the bobolink.

(p. 327.) What is said of the character of the elephant? — Of his trunk? — (p. 328.) Of the effect of education upon him? — To what uses is he put? — How is he directed? (p. 329.) Describe his use of water. — His bathing and swimming. How is he managed by his conductor? (p. 330.) Give an account of the Versailles elephant. What is said of the wild dog? — Of the domestic? — Of the shepherd's dog? — (p. 331.) Of the dog of the Roman beggar? — What other examples of their docility? — Of the Edinburgh grocer's dog? (p. 332.) What is Mr Ray's account of the performances of a horse? What are the characteristics of animals of the ox-kind in a domestic state? Is this their natural character? What is said of the oxen of the Hottentots? (p. 333.) Mention particulars respecting their habits and powers.

What is said of the education of the lower animals? Of the deadly cobra? — (p. 334.) Of fishes, toads, and spiders? — Of the serpent-charmers? Describe an exhibition of them in London. State the opposite accounts given with regard to the extraction of their fangs.

CHAPTER XIII.

OF THE ARTIFICES OF ANIMALS.

(p. 335.) What remark is made concerning monkeys? What is Margraaf's account of those of Brazil? (p. 336.) Give Mr. Parkyns's description of them in Abyssinia. How do they arrange their predatory excursions? Which of them take the lead? Of whom is the main body composed? How do they collect and dispose of their plunder? (p. 337.) How is their sagacity shown in the search for water? Relate an anecdote illustrative of their cunning and adroitness. — Of their imitative propensity. — (p. 338.) Of a fight of a monkey with a dog. — Of one which subdued a vicious horse.

What account is given of the arts used by the deer to deceive dogs? — (p. 339.) By the fallow-deer? — By the roe-deer? — (p. 340.) How does the roe-deer differ from the other kinds of deer? Relate an anecdote of the American deer. Describe the artifices of the hare when hunted. (p. 341.) Describe the character of the fox. — His habitation and manner of life. — (p. 342.) His expedients for securing his prey and escaping from his pursuers. — His food. — His love for honey, and attacks on the nests of bees. — The antipathy of birds to him.

(p. 343.) How does the glutton kill the fallow-deer? — In what country is this? Give an account of the rats of Kamtschatka.

(p. 344.) What is the manner in which rapacious birds seek their prey? — How are they foiled by the smaller? Describe an expedient of the raven. — Of the crow. (p. 345.) Of the nine-killer hawk.

What account is given of the artifices of the inhabitants of the ocean? — (p. 346.) Of insects? — Of the spider? How long has it been known to live without food? Describe the ant-lion. — Its hole for the capture of its prey. (p. 347.) How does it proceed in its construction? Describe a contest between a spider and an ant-lion.

CHAPTER XIV.

ASSOCIATION OF ANIMALS.

(p. 348.) What is the difference between the principle of association in Man and in other animals? What varieties in the objects for which animals associate, and in the disposition which induces them? (p. 349.) How is it with the larger beasts of prey? — With the inferior ones? For what purposes do the herbivorous quadrupeds associate? How do they repel their enemies? (p. 350.) For what purposes do the smaller quadrupeds associate? Which of them associate for the purpose of building their habitations?

What are the social habits of the nobler birds of prey? — Of vultures? (p. 351.) Give an account of the association of other birds. — An anecdote of the sea-fowl in the Shetland Isles. What are the social traits of the parrot? (p. 352.) Describe the gatherings of the passenger-pigeon of America. Give a description of their flight. — And their probable numbers.

(p. 353.) What is stated of the swarms of insects? — Of those of locusts? — Of the use of locusts as food? — (p. 354.) Of the societies of caterpillars? What remark is made concerning the societies of the social insects? Give an account of the nature of the government of the honey-bees. — Of the relation of the queen to the swarm. (p. 355.) Describe the use made by ants of the aphides, or plant-lice. Give Huber's account of his observation of this phenomenon. Upon what terms do the ants and aphides live together? (p. 356.) Describe the system of slavery as practised by the amazon ants. Do there appear to be any regular chiefs among ants? What is the nature of their government?

CHAPTER XV.

OF THE HOSTILITIES OF ANIMALS, AND THE DESTRUCTION OF ANIMAL LIFE.

(p. 357.) Do Man and animals usually reach the natural term of their existence? What part does man take in the destruction of life? What animals come next to him in this respect? (p. 358.) How is it with the inhabitants of the ocean?

What is of the most immediate necessity to life? What want is next to it? What is the predominant feeling in animals, proceeding from this want? (p. 359.) Describe the influence which this appetite for food has upon animals. — In the wolf. — In the eagle. Relate anecdotes of the attacks of eagles on mankind. By what other causes is life sacrificed? (p. 360.) Give examples of various modes of destruction. How is this immense destruction compensated? What evidences are there of a corresponding fecundity of animals? — Among quadrupeds? — And fishes? (p. 361.) Is this true of the larger inhabitants of the ocean?

What other causes are there for the destruction of life? What is said of the destructive propensity in Man? — (p. 362.) In animals? — In the dog, &c.? (p. 363.) What is said of the moral character of this propensity in Man? What animals resemble him most in this respect? Can a purpose always be supposed to exist for this destruction? (p. 364.) How is it with bees and wasps? Give an account of a remarkable battle, narrated by Mr. Willard, among ants. (p. 366.) Can any definite purpose be assigned for this contest? Describe the combats of ants as related by Huber. (p. 368.) Are their ordinary occupations suspended during these contests? What is said of their recognizing always those of their own community? Relate a remarkable example of this from Huber. (p. 369.) For what purpose do the Amazon ants employ the Negro ants? In what stage of existence are they seized? (p. 370.) Describe one of the predatory excursions of the Amazons. What species of ant is made captive in the same way? (p. 371.) What duty is afterwards performed by the Negro ants? What other species undertakes similar enterprises? Give an account of one of them. (p. 372.) What is the relation of the captives to the community? — Of which kind of ants is this account strictly true? (p. 373.) What is Huber's account of apparent games and sports among ants? Dr. Livingstone's account of the ants of South Africa.

CHAPTER XVI.

DURATION OF LIFE.

(p. 374.) Have we any conception either of life or death? Are the changes to which organized beings are subject confined to the materials of which they are composed, or do they extend to the laws of their organization? Do we see any necessary connection between these changes? (p. 375.) How far is the effect of time on an animal like the wearing out of a machine? Is the comparison a just one? Can we conceive of the extinction of the power which maintains organization? (p. 376.) What are some of the common explanations of the effects of age? — Are they satisfactory? State the theory which best explains the phenomena of living bodies, and the changes they undergo in time. — (p. 377.) Does it regard life as the cause or the result of organization? What characteristic of the common power of matter renders it improbable that they are the cause of organization? With what great question is this subject connected? How then can we best conceive of life? How is this conception illustrated by the analogy of a machine? (p. 378.) How is it applied to the successive phenomena of the different ages of life, and its cessation?

Is there reason to believe that the duration of human life has varied during the historic ages? (p. 379.) State some examples of longevity. — As given by Pliny. — In Russia in modern times. — In New Hampshire. — (p. 380.) In England. Describe the case of Henry Francisco, as related by Professor Silliman.

(p. 382.) What is said of the duration of life among the Mammalia? — Among Birds? — Reptiles and Fishes? — Among Insects? (p. 383.) When the existence of insects is protracted, is there any extension of their period of activity? — What relation may this have to the duration of human life?

What is the character of common opinions on the subject of longevity ? — Why is this ? — (p. 384.) How is long life most probably to be attained ? Is there anything in hereditary and individual disposition ? — In a strong constitution and uniform health ? What important distinction is pointed out ? What general conditions contribute to long life ? — (p. 385.) What particular conditions ? What is said of air ? — Of food ? — Of labor and exercise ? — Of moral excitement ? (p. 386.) What remark is made in respect to deferring attention to the means for long life ?

CHAPTER XVII.

INSTINCT AND INTELLIGENCE, AND THE MENTAL CONSTITUTION OF ANIMALS.

What is referred to as a distinguishing characteristic of things having life ? What contrast is pointed out between inorganic and organic things in respect to their individuality ? (p. 387.) Can the forces of one living system have any interchangeable relations with those of another ? How far does individuality extend ? — What illustration is given of this ? — How is this principle applied to the intelligence with which the operations of the inorganic and organic creation are carried on ? (p. 388.) Are the functions of plants directed by intelligence ? Are the same functions also carried on by animals ? What functions have animals beside these ? Are we sensible of those functions which we have in common with plants ? What is said of their reciprocal relations and essential unity ? (p. 389.) From what principle do instinctive operations proceed ? — From what principle intelligent ones ? Describe the three classes of operations by which the economy of animals is carried on. What remark is made concerning the third class ? What resemblance is pointed out between instinctive operations and those performed by habit ? (p. 390.) What is said of the relative part taken by instinct and intelligence, especially in man ? What is the part taken by the will in muscular motion ? What part is taken by instinct in some intellectual operations ? — In numerical calculations ? — In the education of the senses and in speech? (p. 391.) What analogy exists between certain voluntary and involuntary operations ? — Examples. How is this illustrated in the bee and torpedo ? — In the maternal instinct of insects ? (p. 392.) What are the different degrees in which the innate presence of knowledge and the power of acquiring it are possessed by different animals ?

What are the difficulties of this inquiry ? (p. 393.) Mention some examples of vegetable instinct. — In tendrils. — In the palm-tree. — In the screw-pine. — In Indian corn. What comparison is drawn between the economy of the social insects and the internal economy of the human body ? — (p. 394.) And also the process of repair and regeneration of organs ? How is the case different in the higher animals ? How do they differ in their amount of knowledge and capacity for improving upon instinct? (p. 395.) Illustrate these remarks by the instance of the beaver. What is its original instinct as illustrated in its young? How is this modified by circumstances? How is their instinct for migration displayed by wild geese? (p. 396.) What examples are there of long journeys performed under the direction of an intelligent principle? Mention an example of apparent distinct intelligence in ants. — And one of an opposite kind.

(p. 397.) What is the influence of apprehension of danger in suggesting expedients to animals? Mention some example of sagacious conduct in animals. What is implied in these examples? Mention other examples of a higher kind. (p. 398.) What course of observation and reasoning is here indicated?

Are animals ever excited to action by feelings and emotions like those of men? Relate an anecdote concerning swallows from Cuvier. — (p. 399.) Of swans, &c. What are these examples of? — Relate examples of the influence of the maternal instinct in the cat. — The martin. — (p. 400.) The shepherd's dog. — Of a feeling of mutual kindness in animals. Is this a common exhibition? What instances are related of the influence of attachment to human individuals? — In the horse? — (p. 401.) In dogs? What examples are given of manœuvres apparently for exercise or amusement? — In ants? — In robins?

(p. 402.) Are the qualities there exhibited to be regarded as indicative of the general character of the animals concerned? What is the probable nature of the impulse in such instances? How is it with ourselves? What would be the result if the elephant could always exert the same sagacity that he does under particular circumstances? — (p. 403.) What is his character in an uneducated state?

What are the several parts taken by instinct and intelligence in directing the operations of animals? What is the office of instinct where it is the only principle? (p. 404.) How does intelligence coöperate with it where this principle is combined with it? What are examples of instinct alone? — Of intelligence combined with it? In what animals are these principles severally exhibited? Is intelligence probably ever the predominant one except in man? What animals may be taken as representatives of the two principles? How are the insect and man contrasted?

(p. 405.) Do the faculties of man differ from those of other animals in degree or in kind? What motives to action has man beyond those of animals? Are they essentially different? — And do they account for his superiority?

(p. 406.) To what is his superiority to be attributed? Have animals any idea of moral distinctions? Can they be made to have any? What is our feeling with regard to this point? Have they any capacity for the religious sentiment? (p. 407.) What remark is made concerning this sentiment among mankind?

CHAPTER XVIII.

CONCLUSION.

What general remark is made on the kingdom of life? What is said of the general plan of creation? (p. 408.) Is this plan carried on with perfect regularity? What exceptions are there? What is the essential character of the plan? (p. 409.) Should different views of the mode of creation make any difference in our views of its connection with the Creator? What views are most congenial to the sentiments of our nature, and are in conformity with the relation which exists between Man and his Maker? (p. 410.) What was the original condition of the earth? What changes occurred before the introduction of Life? Was its progress unimpeded? How was it resisted? What is said of the nature and duration of the contest of life with the inorganic forces? (p. 411.) Has it terminated? In what respect is life a feeble power? By what attributes is this feebleness compensated? (p. 412.) By what kind of causes were the changes that took place in the first two eras of creation brought about?

(p. 413.) With what event did the third era in creation begin? What constitutes the peculiar feature of this era? What is the resemblance pointed out between the introduction of the organic into the inorganic, and of the spiritual into the organic? (p. 414.) Is there anything in the work of preparation which indicates the character of that to which it leads? Can we determine the period of the successive introduction of these new elements into creation? What remarks are made on this subject.

(p. 415.) What attributes of the Deity are successively illustrated in these three eras? What is the characteristic of the first? — Of the second? (p. 416.) Describe the changes which take place in the third era? What assurance have we of the ultimate triumph of the principle introduced in it? What views of our relation to the Deity are suggested?

(p. 417.) What is said of the legitimate connection of this subject with Philosophy and Science? — Of its intrinsic importance? What is the prevalent tendency of modern science? To what conceptions of Deity does it lead? (p. 418.) — To what views of Revelation?

THE END.