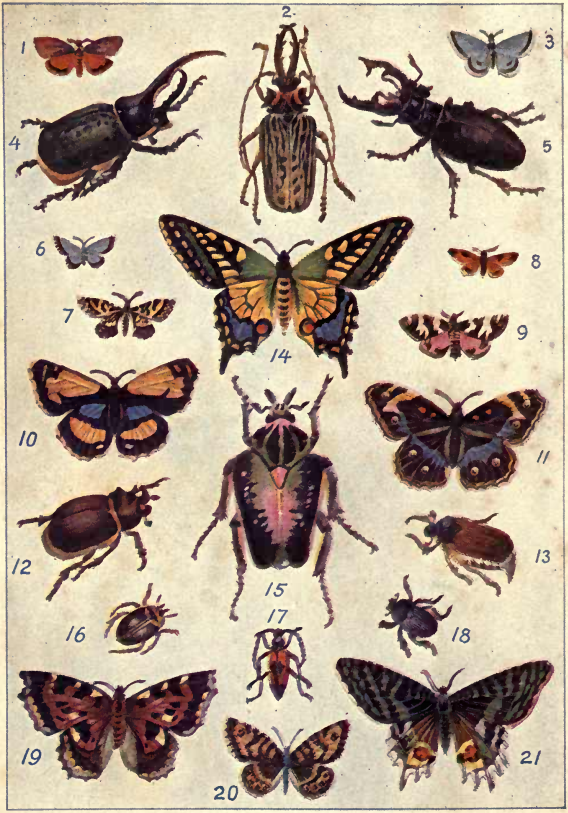

Butterflies and Other Insects

1, Calimorpha; 2, Prionus Cervicornus; 3, 6, Licæna; 4, Oryctes Hercules; 5, Lucanus Cervus; 7, Zeryntina; 8, Lithosia; 9, Arctia; 10, Cynthia; 11, Papilio Œnora; 12, Oryctes Nasicornis; 13, Melolontha; 14, Papilio Machaon; 15, Goliathus; 16, Ditiscus; 17, Leptura; 18, Geotrupes; 19, 20, Vanessa; 21, Urania

THE STORY OF THE UNIVERSE

Told by Great Scientists and Popular Authors

COLLECTED AND EDITED

By ESTHER SINGLETON

Author of "Turrets, Towers and Temples," "Wonders of Nature," "The World's Great Events," "Famous Paintings," Translator of Lavignac's "Music Dramas of Richard Wagner"

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THE
STORY OF THE UNIVERSE

OMNIPRESENCE OF LIFE
—George Henry Lewes

COME with me, and lovingly study Nature, as she breathes, palpitates, and works under myriad forms of Life—forms unseen, unsuspected, or unheeded by the mass of ordinary men. Our course may be through park and meadow, garden and lane, over the swelling hills and spacious heaths, beside the running and sequestered streams along the tawny coast, out on the dark and dangerous reefs, or under dripping caves and slippery edges. It matters little where we go: everywhere—in the air above, the earth beneath, and waters under the earth —we are surrounded with Life. Avert your eyes a while from our human world, with its ceaseless anxieties, its noble sorrow, poignant, yet sublime, of conscious imperfection aspiring to higher states, and contemplate the calmer activities of that other world with which we are so mysteriously related. I hear you exclaim,

"The proper study of mankind is man;"

nor will I pretend, as some enthusiastic students seem to think, that

"The proper study of mankind is *cells;*"

but agreeing with you, that man is the noblest study, I would suggest that under the noblest there are other problems which we must not neglect. Man himself is imperfectly known, because the laws of universal Life are imperfectly known. His life forms but one grand illustration of Biology—the science of Life—as he forms but the apex of the animal world.

Our studies here will be of Life, and chiefly of those minuter or obscurer forms which seldom attract attention. In the air we breathe, in the water we drink, in the earth we tread on, Life is everywhere. Nature *lives:* every pore is bursting with Life; every death is only a new birth, every grave a cradle. And of this we know so little, think so little! Around us, above us, beneath us, that great mystic drama of creation is being enacted, and we will not even consent to be spectators! Unless animals are obviously useful or obviously hurtful to us, we disregard them. Yet they are not alien, but akin. The Life that stirs within us stirs within them. We are all "parts of one transcendent whole." The scales fall from our eyes when we think of this; it is as if a new sense had been vouchsafed to us, and we learn to look at Nature with a more intimate and personal love.

Life everywhere! The air is crowded with birds—beautiful, tender, intelligent birds—to whom life is a song and a thrilling anxiety, the anxiety of love. The air is swarming with insects—those little animated miracles. The waters are peopled with innumerable forms, from the animalcule, so small that one hundred and fifty millions of them would not weigh a grain, to the whale, so large that it seems an island as it sleeps upon the waves. The bed of the seas is alive with polypes, crabs, star-fishes, and with sand-numerous shell-animalcules. The rugged face of rocks is scarred by the silent boring of soft creatures, and blackened with countless mussels, barnacles, and limpets.

Life everywhere! on the earth, in the earth, crawling, creeping, burrowing, boring, leaping, running. If the sequestered coolness of the wood tempt us to saunter into its checkered shade, we are saluted by the murmurous din of insects, the twitter of birds, the scrambling of squirrels, the startled rush of unseen beasts, all telling how populous is this seeming solitude. If we pause before a tree, or shrub, or plant, our cursory and half-abstracted glance detects a colony of various inhabitants. We pluck a flower, and in its bosom we see many a charming insect busy at its appointed labor. We pick up a fallen leaf, and if nothing is visible on it, there is probably the trace of an insect larva hidden in its tissue, and awaiting there development. The drop of dew upon this leaf will probably contain its animals, visible under the microscope. This same microscope reveals that the *blood-rain* suddenly appearing on bread, and awakening superstitious terrors, is nothing but a collection of minute animals (Monas prodigiosa); and that the vast tracts of snow which are reddened in a single night owe their color to the marvelous rapidity in reproduction of a minute plant (Protococcus nivalis). The very mould which covers our cheese, our bread, our jam, or our ink, and disfigures our damp walls, is nothing but a collection of plants. The many-colored fire which sparkles on the surface of a summer sea at night, as the vessel plows her way, or which drips from the oars in lines of jeweled light, is produced by millions of minute animals.

Nor does the vast procession end here. Our very mother-earth is formed of the débris of life. Plants and animals which have been built up its solid fabric. We dig downward thousands of feet below the surface, and discover with surprise the skeletons of strange, uncouth animals, which roamed the fens and struggled through the woods before man was. Our surprise is heightened when we learn that the very quarry itself is mainly composed of the skeletons of microscopic animals; the flints which grate beneath our carriage wheels are but the remains of countless skeletons. The Apennines and Cordilleras, the chalk cliffs so dear to homeward-nearing eyes—these are the pyramids of bygone generations of atomies. Ages ago these tiny architects secreted the tiny shells which were their palaces; from the ruins of these palaces we build our Parthenons, our St. Peters, and our Louvres. So revolves the luminous orb of Life! Generations follow generations; and the Present becomes the matrix of the Future, as the Past was of the Present—the Life of one epoch forming the prelude to a higher Life.

When we have thus ranged air, earth, and water, finding everywhere a prodigality of living forms, visible and invisible, it might seem as if the survey were complete. And yet it is not so. Life cradles within Life. The bodies of animals are little worlds, having their own animals and plants. A celebrated Frenchman has published a thick octavo volume devoted to the classification and description of *The Plants which Grow on Men and Animals;** and many Germans have described the immense variety of animals which grow on and in men and animals; so that science can boast of a parasitic Flora and Fauna. In the fluids and tissues, in the eye, in the liver, in the stomach, in the brain, in the muscles, parasites are found, and these parasites have often *their* living parasites in them!

We have thus taken a bird's-eye view of the field in which we may labor. It is truly inexhaustible. We may begin where we please, we shall never come to an end; our curiosity will never slacken.

> "And whosoe'er in youth
> Has through ambition of his soul given way
> To such desires, and grasp'd at such delights,
> Shall feel congenial stirrings late and long."

As a beginning, get a microscope. If you can not borrow, boldly buy one. Few purchases will yield you so much pleasure; and, while you are about it, do, if possible, get a good one. Spend as little money as you can on accessory apparatus and expensive fittings, but get a good stand and good glasses. Having got your instrument, bear in mind these two important trifles—work by daylight, sel-

* Charles Robin: "Histoire Naturelle des Végétaux Parasites qui croissent sur l'Homme et sur les Animaux Vivants." 1853.

dom or never by lamplight; and keep the unoccupied eye *open.* With these precautions you may work daily for hours without serious fatigue to the eye.

Now where shall we begin? Anywhere will do. This dead frog, for example, that has already been made the subject of experiments, and is now awaiting the removal of its spinal cord, will serve us as a text from which profitable lessons may be drawn. We snip out a portion of its digestive tube, which, from its emptiness, seems to promise little; but a drop of the liquid we find in it is placed on a glass slide, covered with a small piece of very thin glass, and brought under the microscope. Now look. There are several things which might occupy your attention, but disregard them now to watch that animalcule which you observe swimming about. What is it? It is one of the largest of the Infusoria, and is named Opalina. When I call this an Infusorium I am using the language of text-books; but there seems to be a growing belief among zoologists that the Opalina is not an Infusorium, but the infantile condition of some worm (Distoma?). However, it will not grow into a mature worm as long as it inhabits the frog; it waits till some pike or bird has devoured the frog, and then, in the stomach of its new captor, it will develop into its mature form—then, and not till then. This surprises you. And well it may; but thereby hangs a tale, which to unfold—for the present, however, it must be postponed, because the Opalina itself needs all our notice.

Observe how transparent it is, and with what easy, undulating grace it swims about; yet this swimmer has no arms, no legs, no tail, no backbone to serve as a fulcrum to moving muscles—nay, it has no muscles to move with. 'Tis a creature of the most absolute abnegations—sans eyes, sans teeth, sans everything; no, not sans everything, for, as we look attentively, we see certain currents produced in the liquid, and, on applying a higher magnifying power, we detect how these currents are produced. All over the surface of the Opalina there are delicate hairs in incessant vibration; these are the *cilia.** They lash the water, and the animal is propelled by their strokes, as a galley by its hundred oars. This is your first sight of that ciliary action of which you have so often read, and which you will henceforth find performing some important service in almost every animal you examine. Sometimes the cilia act as instruments of locomotion; sometimes as instruments of respiration, by continually renewing the current of water; sometimes as the means of drawing in food, for which purpose they surround the mouth, and by their incessant action produce a small whirlpool into which the food is sucked. An example of this is seen in the Vorticella.

Having studied the action of these cilia in microscopic animals, you will be prepared to understand their office in your own organism.

It is an interesting fact, that while the direction in which the cilia propel fluids and particles is gen-

* From *cilium*, a hair.

erally toward the interior of the organism, it is sometimes *reversed,* and, instead of beating the particles inward, the cilia energetically beat them back if they attempt to enter. Fatal results would ensue if this were not so. Our air-passages would no longer protect the lungs from particles of sand, coal-dust, and filings flying about the atmosphere; on the contrary, the lashing hairs which cover the surface of these passages would catch up every particle and drive it onward into the lungs. Fortunately for us, the direction of the cilia is reversed, and they act as vigilant janitors, driving back all vagrant particles with a stern "No admittance, *even* on business!" In vain does the whirlwind dash a column of dust in our faces—in vain does the air, darkened with coal-dust, impetuously rush up the nostrils; the air is allowed to pass on, but the dust is inexorably driven back.

The swimming apparatus of the Opalina has led us far away from the little animal who has been feeding while we have been lecturing. At the mention of feeding you naturally look for the food that is eaten, the mouth and stomach that eat. But I hinted just now that this ethereal creature dispenses with a stomach, as too gross for its nature, and, of course, by a similar refinement, dispenses with a mouth. Indeed, it has no organs whatever except the cilia just spoken of.

And this leads us to consider what biologists mean by an *organ:* it is a particular portion of the body set apart for the performance of some particular function. The whole process of development is this setting apart for special purposes. The starting-point of Life is a single cell—that is to say, a microscopic sac, filled with liquid and granules, and having within it a nucleus, or smaller sac. Paley has somewhere remarked that in the early stages there is no difference discernible between a frog and a philosopher. It is very true—truer than he conceived. In the earliest stage of all, both the Batrachian and the Philosopher are nothing but single cells, although the one cell will develop into an Aristotle or a Newton, and the other will get no higher than the cold, damp, croaking animal which boys will pelt, anatomists dissect, and Frenchmen eat. From the starting-point of a single cell this is the course taken: the cell divides itself into two, the two become four, the four eight, and so on, till a mass of cells is formed not unlike the shape of a mulberry. This mulberry-mass then becomes a sac, with double envelopes or walls; the inner wall, turned toward the yelk, or food, becomes the *assimilating* surface for the whole; the outer wall, turned toward the surrounding medium, becomes the surface which is to bring frog and philosopher into contact and relation with the external world—the Non-Ego, as the philosopher in after life will call it. Here we perceive the first grand "setting apart," or *differentiation,* has taken place; the embryo having an assimilating surface, which has little to do with the external world, and a sensitive, contractile surface, which has little to do with the preparation and transport of food. The embryo is no longer a mass of similar cells; it is already become dissimilar, *dif-*

ferent, as respects its inner and outer envelope. But these envelopes are at present uniform; one part of each is exactly like the rest. Let us, therefore, follow the history of Development, and we shall find that the inner wall gradually becomes unlike itself in various parts, and that certain organs, constituting a very complex apparatus of Digestion, Secretion, and Excretion, are all one by one wrought out of it by a series of metamorphoses or *differentiations.* The inner wall thus passes from a simple assimilating surface to a complex apparatus serving the functions of vegetative life.

Now glance at the outer wall: from it also various organs have gradually been wrought; it has developed into muscles, nerves, bones, organs of sense, and brain—all these from a simple homogeneous membrane!

With this bird's-eye view of the course of development you will be able to appreciate the grand law first clearly enunciated by Goethe and Von Baer as the law of animal life, namely, that development is always from the general to the special, from the simple to the complex, from the homogeneous to the heterogeneous, and this by a gradual series of *differentiations.*

Here is our Opalina, for example, without mouth, or stomach, or any other organ. It is an assimilating surface in every part; in every part a breathing, sensitive surface. Living on liquid food, it does not need a mouth to seize or a stomach to digest such food. The liquid, or gas, passes through the Opalina's delicate skin by a process which is called *en-*

dosmosis; it there serves as food; and the refuse passes out again by a similar process, called *exosmosis.* This is the way in which many animals and all plants are nourished. The cell at the end of a rootlet, which the plant sends burrowing through the earth, has no mouth to seize, no open pores to admit the liquid that it needs; nevertheless, the liquid passes into the cell through its delicate cell-wall, and passes from this cell to *other* cells upward from the rootlet to the bud. It is in this way, also, that the Opalina feeds: it is all-mouth, no-mouth; all-stomach, no-stomach. Every part of its body performs the functions which in more complex animals are performed by organs specially set apart. It feeds without mouth, breathes without lungs, and moves without muscles. The Opalina, as I have said, is a parasite. It may be found in various animals, and almost always in the frog.

Nature is economic as well as prodigal of space. She fills the illimitable heavens with planetary and starry grandeurs, and the tiny atoms moving over the crust of earth she makes the homes of the infinitely little. Far as the mightiest telescope can reach, it detects worlds in clusters, like pebbles on the shore of infinitude; deep as the microscope can penetrate, it detects life within life, generation within generation, as if the very universe itself were not vast enough for the energies of life!

THE ANIMAL KINGDOM
—THOMAS H. HUXLEY

AS soon as the labors of anatomists had extended over a sufficiently great variety of animals, it was found that they could be grouped into separate assemblages, the members of each of which, while varying more or less in minor respects, had certain structural features in common, and these common morphological characters became the definition of the group thus formed. The smallest group thus constituted is a *Morphological Species.* A certain number of species having characters in common, by which they resemble one another and differ from all other species, constitutes a *Genus;* a group of genera, similarly associated, constitutes a *Family;* a group of families, an *Order;* a group of orders, a *Class;* a group of classes, a *Sub-kingdom;* while the latter, agreeing with one another only in the characters in which all animals agree, and in which they differ from all plants, make up the *Animal Kingdom.*

Linnæus, living at a time when neither comparative anatomy nor embryology can be said to have existed, based his classification of animals upon such broad resemblances of adult structure and habit as his remarkable sagacity and wide knowledge enabled him to detect. Cuvier and his school devoted themselves to the working out of adult structure, and the *Leçons d'Anatomie Comparée* and the *Règne Animal* are wonderful embodiments of the results of such investigations. But the Cuvierian system ignores development; and it was reserved for Von Baer to show the importance of developmental studies, and to inaugurate the marvelous series of researches which, in the course of the last fifty years, have made us acquainted with the manner of development of every important group of animals. The splendid researches of Cuvier gave birth to scientific palæontology, and demonstrated that, in some cases, at any rate, extinct forms of life present characters intermediate between those of groups which are at present widely different. The investigations of Agassiz upon fossil fishes tended in the same direction, and further showed that, in some cases, the older forms preserve, as permanent features, structural characters which are embryonic and transitory in their living congeners. Moreover, Darwin, Owen, and Wallace proved that, in any great area of geographical distribution, the later tertiary extinct forms are clearly related to those which now exist in the area. As Taxonomic investigations increased in accuracy and in extent, the careful examination of large suites of specimens revealed an unexpected amount of variability in species; and Darwin's investigation of the phenomena presented by animals under domestication proved that forms, morphologically as distinct as admitted natural genera, could be produced by selective breeding from a common stock.

The only genus of animals of which we possess a satisfactory, though still not quite complete, ancestral history, is the genus Equus, the development of which in the course of the Tertiary epoch from an

Anchitherioid ancestor, through the form of Hipparion, appears to admit of no doubt. And all the facts of geology and palæontology not only tend to show that the knowledge of ancestral development is likely long to remain fragmentary, but lead us to doubt whether even such fragments as may be vouchsafed to us by the extension of geological inquiry will ever be sufficiently old, in relation to the whole duration of life on the earth, to give us positive evidence of the nature of the earliest forms of animals.

In the case of an existing animal, it is possible to determine its adult structure and its development, and therefore to assign its place relatively to other animals, the structure and development of which are also known; and, in the case of an extinct animal, it is possible to ascertain certain facts of its structure, and sometimes certain facts of its development, which will justify a more or less positive assignment of its place relatively to existing animals. So far, Taxonomy is objective, capable of proof and disproof, and it should leave speculation aside, until speculation has converted itself into demonstration.

In the present rapidly shifting condition of our knowledge of the facts of animal structure and development, however, it is no easy matter to group these facts into general propositions which shall express neither more nor less than is contained in the facts; and no one can be more conscious of the manifold imperfections of the following attempt at such a classification than the author of it.

In certain of the lower animals, the substance of the body is not differentiated into histogenetic elements; that is, into cells* which, by their metamorphoses, give rise to tissues. In all other animals, on the other hand, the protoplasmic mass, which constitutes the primitive body, is converted into a multitude of cells, which become metamorphosed into the tissues of the body.

For the first of these divisions the old name of Protozoa may be retained; for the second, the title of Metazoa, recently proposed by Haeckel, may be conveniently employed.

The subjoined synopsis indicates the general relations of the different groups of the animal kingdom.

Those who are familiar with the existing condition of our knowledge of animal morphology will be aware that any such scheme must needs, at present, be tentative and subject to extensive revision, in correspondence with the advance of knowledge. Nor will they regard it as any objection to the scheme of classification proposed, that the divisions sketched out may be incapable of sharp definition—the constant tendency of modern investigations being to break through all boundaries of groups, and to fill up the gaps between them by the discovery of transitional forms. In the place of assemblages of distinctly definable groups, which it has hitherto been the object of the taxonomist to define and co-ordinate in precise logical categories, we are gradually learning to substitute series, in which all the modifications by which a fundamental form passes from lower to higher degrees of organic complication are summed up.

* The term "cell" is used here in its broadest sense.

ANIMALIA

I.—PROTOZOA

i. MONERA
Protamœbidæ. Protomonadidæ. Myxastridæ, etc.

ii. ENDOPLASTICA
Amœbidæ. Flagellata. Gregarinidæ. Acinetida. Ciliata. Radiolaria

II.—METAZOA

A. Gastrææ

i. POLYSTOMATA
Porifera (or Spongida)

ii. MONOSTOMATA

1. Archæostomata

a. Scolecimorpha
Rotifera
Turbellaria
Trematoda
Nematoidea
Hirudinea
Oligochæta

β. Cœlenterata
Hydrozoa
Actinozoa

2. Deuterostomata

a. Schizocœla
Annelida (*Polychæta*)
Arthropoda
Gephyrea
Mollusca
Brachiopoda (?)
Polyzoa (?)

b. Enterocœla
Enteropneusta
Chætognatha
Echinodermata

c. Epicœla
Tunicata
Vertebrata

B. Agastrææ (provisional)
Acanthocephala. Cestoidea

THE FOUR CLASSES
—Baron Cuvier

If we consider only the organization and nature of animals, without regard to their size, utility, the greater or less knowledge we have of them, and other accessory circumstances, we shall find there are four principal forms, four general plans, if it may be so expressed, on which all animals seem to have been modeled, and whose ulterior divisions, whatever be the titles with which naturalists have decorated them, are merely slight modifications, founded on the development or addition of certain parts, which produce no essential change in the plan itself.

In the first of these forms, which is that of man and of the animals most nearly resembling him, the brain and principal trunk of the nervous system are inclosed in a bony envelope, formed by the cranium and vertebræ; to the sides of this intermedial column are attached the ribs and bones of the limbs, which form the framework of the body; the muscles generally cover the bones, whose motions they occasion, while the viscera are contained within the head and trunk. Animals of this form we shall denominate Animalia Vertebrata. They have, all, red blood, a muscular heart, a mouth furnished with two jaws situated either above or before each other, distinct organs of sight, hearing, smell, and taste placed in the cavities of the face, never more than four limbs, the sexes always separated, and a very similar distribution of the medullary masses and the principal branches of the nervous system.

By a closer examination of each of the parts of this great series of animals, we always discover some analogy, even in species the most remote from each other; and may trace the gradations of one same plan from man to the last of the fishes.

In the second form there is no skeleton; the muscles are merely attached to the skin, which constitutes a soft contractile envelope, in which, in many species, are formed stony plates, called shells, whose position and production are analogous to those of the mucous body. The nervous system is contained within this general envelope along with the viscera, and is composed of several scattered masses connected by nervous filaments; the chief of these masses is placed on the æsophagus and is called the brain. Of the four senses, the organs of two only are observable, those of taste and sight, the latter of which are even frequently wanting. One single family alone presents organs of hearing. There is always, however, a complete system of circulation, and particular organs for respiration. Those of digestion and secretion are nearly as complex as in the vertebrata. We will distinguish the animals of this second form by the appellation of Animalia Mollusca.

Although, as respects the external configuration of the parts, the general plan of their organization is not as uniform as that of the vertebrata, there is always an equal degree of resemblance between them in the structure and the functions.

The third form is that remarked in worms, insects, etc. Their nervous system consists of two long cords, running longitudinally through the abdomen, with which they communicate by filaments that encircle the æsophagus like a necklace. The covering or envelope of the body is divided by transverse folds into a certain number of rings whose teguments are sometimes soft, and sometimes hard; the muscles, however, being always situated internally. Articulated limbs are frequently attached to the trunk; but very often there are none. We will call these animals Animalia Articulata, or articulated animals, in which is observed the transition from the circulation in closed vessels to nutrition by imbibition, and the corresponding one of respiration in circumscribed organs, to that effected by tracheæ or air-vessels distributed throughout the body. In them the organs of taste and sight are the most distinct; one single family alone presenting that of hearing. Their jaws, when they have any, are always lateral.

The fourth form, which embraces all those animals known by the name of zoophytes, may also be properly denominated Animalia Radiata, or radiated animals. We have seen that the organs of sense and motion in all the preceding ones are symmetrically arranged on the two sides of an axis. There is a posterior and anterior dissimilar face. In this last division they are disposed by rays round a centre; and this is the case even when they consist of but two series, for then the two faces are similar. They approximate to the homogeneity of plants, having no very distinct nervous system or particular organs of sense; in some of them it is even difficult to discover a vestige of circulation; their respiratory organs are almost universally seated on the surface of the body, the intestine in the greater number is a mere sac without issue, and the lowest of the series are nothing but a sort of homogeneous pulp, endowed with motion and sensibility.

DEEP SEA FAUNA
—LORD KELVIN

NEARLY all the animals at extreme depths—practically all the animals, for the small number of higher forms feed upon these—belong to one sub-kingdom, the Protozoa; whose distinctive character is that they have no special organs of nutrition, but absorb nourishment through the whole surface of their jelly-like bodies. Most of these animals secrete exquisitely formed skeletons, some of silica, some of carbonate of lime. There is no doubt that they extract both these substances from the sea-water; and it seems more than probable that the organic matter which forms their soft parts is derived from the same source. It is thus quite intelligible that a world of animals may live in these dark abysses, but it is a necessary condition that they must chiefly belong to a class capable of being supported by absorption through the surface of their bodies of matter in solution, developing but little heat, and incurring a very small amount of waste by any manifestation of vital activity. According to this view it seems probable that at all periods of the earth's history, some form of the Protozoa—rhizopods, sponges, or both—predominated greatly over all other forms of animal life in the depths of the warmer regions of the sea. The rhizopods, like the corals of a shallower zone, form huge accumulations of carbonate of lime, and it is probably to their agency that we must refer most of those great bands of limestone which have resisted time and change, and come in here and there with their rich imbedded lettering to mark like milestones the progress of the passing ages.

We find the first and simplest of the invertebrate sub-kingdoms, the Protozoa, represented by three of its classes—the monera, the rhizopoda, and the sponges. The monera have been defined as a distinct class by Professor Ernst Haeckel, of a vast assemblage of almost formless beings apparently absolutely devoid of internal structure, and consisting simply of living and moving expansions of jelly-like protoplasm. The monera pass into the rhizopoda, which give a slight indication of advance in the definite form of the graceful, calcareous, shell-like structures which most of them secrete, and the two groups may be taken together.

The dredging at 2,435 fathoms at the mouth of the Bay of Biscay gave a very fair idea of the condition of the bottom of the sea over an enormous area, as we know from many observations which have now been made with the various sounding instruments contrived to bring up a sample of the bottom. Under the microscope the surface-layer was found to consist chiefly of entire shells of Globigerina bulloides, large and small, and fragments of such shells mixed with a quantity of amorphous calcareous matter in fine particles, a little fine sand, and many spicules, portions of spicules, and shells of Radiolaria, a few spicules of sponges, and a few frustules of diatoms.

In this dredging, as in most others in the bed of the Atlantic, there was evidence of a considerable quantity of soft gelatinous organic matter, enough to give a slight viscosity to the mud of the surface-layer. This gelatinous matter is capable of a certain amount of movement, and there can be no doubt that it manifests the phenomena of a very simple form of life.

To this organism, if a being can be so called which shows no trace of differentiation of organs, consisting apparently of an amorphous sheet of a protein compound, irritable to a low degree and capable of assimilating food, Professor Huxley has given the name of Bathybius haeckelii. The circumstance which gives its special interest to Bathybius is its enormous extent: whether it be continuous in one vast sheet, or broken up into circumscribed individual particles, it appears to extend over a large part of the bed of the ocean; and as no living thing, however slowly it may live, is ever perfectly at rest, but is continually acting and reacting with its surroundings, the bottom of the sea becomes like the surface of the sea and of the land—a theatre of change, performing its part in maintaining the "balance of organic nature."

Living upon and among this Bathybius, we find a multitude of other protozoa—foraminifera and other rhizopods, radiolarians, and sponges; and we as yet know very little of the life-history of these groups.

Many foraminifera of different groups inhabit the deep water, lying upon or mixed in the upper layer of the globigerina ooze, or fixed to some foreign body, such as a sponge, coral, or stone; and all of these are remarkable for their large size.

The few hauls of the dredge which we have already had in deep water have been enough to teach us that our knowledge of sponges is in its infancy—that those which we have collected from shallow water along our shores, and even those few which have been brought up from deep water on fishing lines, and have surprised us by the beauty of their forms and the delicacy of their lustre, are the mere margin and remnant of a wonderfully diversified sponge-fauna which appears to extend in endless variety over the whole of the bottom of the sea.

The most remarkable new forms are referable to the group which seems to be in a sense special to deep water, the Hexactinellidæ. One of the most abundant and singular forms belonging to this order, Holtenia carpenteri, is an oval or sphere 90 to 100 mm. in height, with one large oscular opening at the top about 30 mm. in diameter, whence a simple cylindrical cavity cupped at the bottom passes down vertically into the substance of the sponge to the depth of 55 mm. The outer wall of the sponge consists of a complicated network of the cross-like heads of five-rayed spicules. One ray of each spicule dips directly into the body of the sponge, and the other four, which are at right angles to it, form a cross on the surface, giving it a beautiful stellate appearance. The silicious rays of one star curve toward and meet the rays of the neighboring stars, and run parallel with them. All the rays of all the spicules are thickly invested with consistent semi-transparent gelatinous matter, which binds their concurrent branches together by an elastic union, and fills up the angles of the meshes with softly curved viscous masses. This arrangement of the spicules, free and yet adhering together by long elastic connections, produces a strong, flexible, and very extensible tissue. The cylindrical oscular cavity within the sponge is lined with nearly the same kind of network.

When the sponge is living, the interstices of the silicious network are filled up both outside and in with a delicate fenestrated membrane formed of a glairy substance like white of egg, which is constantly moving, extending or contracting the fenestræ, and gliding over the surface of the spicules. This "sarcode," which is the living flesh of the sponge, contains distributed through it an infinite number of very minute spicules, presenting the most singular and elegant forms very characteristic of each species of sponge. A constant current of water carried along by the action of cilia passes in by apertures in the outer wall, courses through the passages in the loose texture of the intermediate sponge-substance carrying organic matter in solution and particles of nourishment into all its interstices, and finally passes out by the large "osculum" at the top. Over the upper third of the sponge a multitude of radiating rigid silicious spicules form a kind of ornamental frill, and from the lower third a perfect maze of delicate glassy filaments, like fine white hair, spread out in all directions, penetrating the semi-fluid mud, and supporting the sponge in its precarious bed by increasing its surface indefinitely while adding but little to its weight.

This is only one of the ways by which sponges anchor themselves in the ooze of the deep sea. Hyalonema sends right down through the soft mud a coiled wisp of strong spicules, each as thick as a knitting needle, which open out into a brush as the bed gets firmer, and fix the sponge in its place somewhat on the principle of a screw pile. A very singular sponge from deep water off the Lofoten Islands spreads into a thin circular cake, and adds to its surface by sending out a flat border of silky spicules, like a fringe of white floss round a little yellow mat; and the lovely Euplectella, whose beauty is imbedded up to its fretted lid in the gray mud of the seas of the Philippines, is supported by a frill of spicules standing up round it like Queen Elizabeth's ruff.

The sponges of the deep-water ooze are by no means confined to one group. The Hexactinellidæ are perhaps the most abundant, but corticate sponges even, closely allied to those which look so rigid when fixed to stones in shallow water, send out long anchoring spicules and balance themselves in the soft mud; and off the coast of Portugal Mr. Gwyn Jeffreys dredged in 1870 several small forms of the Halichondridæ, with long supporting fibrous beards.

From its appearance when brought up Holtenia evidently lives buried in the mud to its upper fringe of spicules. When freshly dredged, it is loaded with pale gray semi-fluid sarcode, full of Globigerinæ, Triloculinæ, and other rhizopods, and covered in our northern localities with the little ophiurid Amphiura abyssicola, Sars, and the exquisitely delicate transparent clam, Pecten viterus Chemnitz. Holtenia extends from the Butt of Lewis to Gibraltar, in from 500 to 1,000 fathoms.

In the Hexactinellidæ all the spicules, so far as we know, are formed on the hexradiate plan; that is to say, there is a primary axis, which may be long or short, and at one point four secondary rays cross this central shaft at right angles. In many of the Hexactinellidæ the spicules are all distinct, and combined, as in Holtenia, by a small quantity of nearly transparent sarcode; but in others, as in "Venus's flower-basket," and the nearly equally beautiful genera Iphiteon, Aphrocallistes, and Farrea, the spicules run together and make a continuous silicious network. When this is the case the sponge may be boiled in nitric acid, and all the organic matter and other impurities thus removed, when the skeleton comes out a lovely lacy structure of the clearest glass. The six-rayed form of the spicules gives the network which is the result of their fusion great flexibility of design, with a characteristic tendency, however, to square meshes.

Off the Butt of Lewis, in water of 450 to 500 fathoms, we met on two occasions with full-grown specimens of a species of the remarkable genus

Hyalonema, with the coils in the larger examples upward of 40 centimetres in length.

A bundle of from 200 to 300 threads of transparent silica, glistening with a silky lustre, like the most brilliant spun-glass—each thread from 30 to 40 centimetres long, in the middle the thickness of a knitting-needle, and gradually tapering toward either end to a fine point; the whole bundle coiled like a strand of rope into a lengthened spiral, the threads of the middle and upper portions remaining compactly coiled by a permanent twist of the individual threads; the lower part of the coil, which, when the sponge is living, is imbedded in the mud, frayed out so that the glassy threads stand separate from one another, like the bristles of a glittering brush; the upper portion of the coil close and compact, imbedded perpendicularly in a conical or cylindrical sponge; and usually part of the upper portion of the silicious coil, and part of the sponge-substance, covered with a brownish leathery coating, whose surface is studded with the polypes of an alcyonarian zoophyte—such is the general effect of a complete specimen of Hyalonema.

The genus was first known in Europe by specimens brought from Japan by the celebrated naturalist and traveler, Von Siebold; and Japanese examples of Hyalonema sieboldi, Gray, may now be found more or less perfect in most of the European museums. When the first specimen of Hyalonema was brought home, the other vitreous sponges which approach it so closely in all essential points of structure were unknown.

In essential structure Hyalonema very closely resembles Holtenia, and the more characteristic forms of the Hexactinellidæ. On one of the Holteniæ from the Butt of Lewis, there was a little accumulation of greenish granular matter among the fibres. On placing this under the microscope it turned out to be a number of very young sponges, scarcely out of their germ state. They were all at first sight very much alike, minute pear-shaped bodies, with a long delicate pencil of silky spicules taking the place of the pear-stalk. On closer examination, however, these little germs proved to belong to different species, each showing unmistakably the characteristic forms of its special spicules. Most of them were the young of Tisiphonia, but among them were several Holteniæ, and one or two were at once referred to Hyalonema. In two or three hauls in the same locality we got them in every subsequent stage—beautiful little pear-shaped things, a centimetre long, with a single osculum at the top, and the wisp like a small brush. At this stage the Palythoa is usually absent, but when the body of the sponge has attained 15 mm. or so in length very generally a little pink tubercle may be detected at the point of junction between the sponge body and the coil, the germ of the first polype.

During Mr. Gwyn Jeffreys's cruise in 1870, two specimens of a wonderful sponge belonging also to the Hexactinellidæ were dredged in 374 fathoms in rocky ground off Cape St. Vincent. The larger of these forms a complete vase of a very elegant form, nearly ninety centimetres in diameter at the top and about sixty in height. The sponge came up folded together, and had much the appearance of a piece of coarse, grayish-colored blanket.

Near the mouth of the Strait of Gibraltar a number of species were taken in considerable quantity, belonging to a group which were at first confused with the Hexactinellidæ, on account of their frequently forming a similar and equally beautiful continuous network of silica, so as to assume the same resemblance to delicate lace when boiled in nitric acid. The Corallio-spongiæ differ, however, from the Hexactinellidæ in one very fundamental character. While in the latter the spicule is hexradiate, in the former it consists of a shaft with three diverging rays at one end.

This group of sponges are as yet imperfectly known. They seem to pass into such forms as Geodia and Tethya; and the typical example with which we are most familiar is the genus Dactylocalyx, represented by the cup-shaped pumice-like masses which are thrown ashore from time to time on the West Indian Islands.

Twelve species of stony corals were dredged in 1869.

From their considerable size, the length and rigidity of their straggling rays, and their habit of clinging to fixed objects, the Echinodermata are not very readily taken by the dredge, but they fall an easy prey to the "hempen tangles." It is possible that this circumstance may to a certain extent exaggerate their apparent abundance at great depths, but we have direct evidence in the actual numbers which are brought up that in some places they must be wonderfully numerous; and we frequently dredge sponges and corals actually covered with them in the attitudes in which they lived, nestling among their fibres and in the angles of their branches. I have counted seventy-three examples of Amphiura abyssicola, small and large, sticking to one Holtenia.

Both on account of their beauty and extreme rarity, and of the important part they have borne in the fauna of some of the past periods of the earth's history, the first order of the Echinoderms, the Crinoidea, has always had a special interest to naturalists; and, on the watch as we were for missing links which might connect the present with the past, we eagerly welcomed any indication of their presence. Crinoids were very abundant in the seas of the Silurian period. But during the lapse of ages the whole order seems to have been worsted in the "struggle for life." They become scarce in the newer Mesozoic beds, still scarcer in the Tertiaries, and up to within the last few years only two living stalked crinoids were known in the seas of the present period, and these appeared to be confined to deep water in the seas of the Antilles, whence fishermen from time to time bring up mutilated specimens on their lines. Their existence has been known for more than a century; but although many eyes have been watching for them, until very lately not more than twenty specimens had reached Europe, and of these only two showed all the joints and plates of the skeleton, and the soft parts were lost in all.

These two species belong to the genus Pentacrinus, which is well represented in the beds of the lias and oolite, and sparingly in the white chalk; and are named respectively Pentacrinus asteria, L., and P. mülleri, Oersted. The first of these has been known in Europe since the year 1755, when a specimen was brought to Paris from the island of Martinique, and described by Guettard in the Memoirs of the Royal Academy of Sciences. For the next hundred years an example turned up now and then from the Antilles.

Pentacrinus asteria may be taken as the type of its order; I will therefore describe it briefly. The animal consists of two well-marked portions, a stem and a head. The stem, which is often from 40 to 60 centimetres in length, consists of a series of flattened calcareous joints; it may be snapped over at the point of junction between any two of these joints, and by slipping the point of a penknife into the next suture a single joint may be removed entire. The joint has a hole in the centre, through which one might pass a fine needle. This hole forms part of a canal filled during life with a gelatinous nutrient matter which runs through the whole length of the stem, branches in a complicated way through the plates of the cup, and finally passes through the axis of each of the joints of the arms, and of the ultimate pinnules which fringe them. On the upper and lower surfaces of the stem-joint there is a very graceful and characteristic figure of five radiating oval leaf-like spaces, each space surrounded by a border of minute alternate ridges and grooves.

The ridges of the upper surface of a joint fit into the grooves of the lower surface of the joint above it; so that, though from being made up of many joints the stem admits of a certain amount of motion, that motion is very limited.

As the border of each star-like figure exactly fits the border of the star above and below, the five leaflets within the border are likewise placed directly one above the other. Within these leaflets the limy matter which makes up the great bulk of the joint is more loosely arranged than it is outside, and five oval bands of strong fibres pass in the interspaces right through the joints, from joint to joint, from one end of the stem to the other. These fibrous bands give the column great strength. It is by no means easily broken even when dead and dry. They also, by their elasticity, admit a certain amount of passive motion. There are no muscles between the joints of the stem, so that the animal does not appear to be able to move its stalk at will. It is probably only gently waved by the tides and currents, and by the movements of its own arms.

In Pentacrinus asteria about every seventeenth joint of the lower mature part of the stem is a little deeper or thicker than the others, and bears a whorl of five long tendrils or cirri. These tendrils have no true muscles; they have, however, some power of contracting round resisting objects which they touch, and there are often star-fishes and other sea animals entangled among them.

Near the head the cirri become shorter and smaller, and their whorls closer. At the top of the stem five little calcareous lumps like buttons stand out from the projecting ridges, and upon these and upon the upper part of the stem the cup which holds the viscera of the animal is placed.

All the ordinary joints of the arms are provided with muscles producing various motions, and binding the joints firmly together. If one of the arms get entangled, or fall into the jaws or claws of an enemy, by a jerk the star-fish can at once get rid of the embarrassed arm; and as all this group have a wonderful power of reproducing lost parts, the arm is soon restored.

Unfortunately, most of the examples of Pentacrinus asteria hitherto procured have had the soft parts destroyed and the disk more or less injured. One specimen, however, in my possession is quite perfect. The body is covered above by a membrane closely tessellated with irregularly formed flat plates. The mouth is a rounded opening of considerable size in the centre of the disk, and opens into a stomach passing into a short curved intestine which ends in a long excretory tube—the so-called "proboscis" of the fossil crinoids—which rises from the surface of the disk near the mouth. From the mouth five deep grooves, bordered on either side by small square plates, run out to the edge of the disk, and are continuous with the grooves on the upper surface of the arms and pinnules, while in the angles between them five thickened masses of the mailing of the disk surround the mouth like valves. These were at first supposed to answer the purpose of teeth. The crinoids, however, are not predatory animals. Their nutrition is effected in a very gentle manner. The grooves of the pinnules and arms are richly ciliated. The crinoid expands its arms like the petals of a full-blown flower, and a current of sea-water bearing organic matter in solution and suspension is carried by the cilia along the brachial and radial grooves to the mouth. In the stomach and intestine the water is exhausted of assimilable matter, and the length and direction of the excretory proboscis prevent the exhausted water from returning at once into the ciliated passages.

Two other fixed crinoids were dredged from the *Porcupine,* and these must be referred to the Apiocrinidæ, which differ from all other sections of the order in the structure of the upper part of the stem.

The Apiocrinidæ attained their maximum during the Jurassic period, when they were represented by many fine species of the genera Apiocrinus and Millericrinus. The chalk genus Bourguetticrinus shows many symptoms of degeneracy. Rhizocrinus loffotensis, M. Sars, was discovered in the year 1864, at a depth of about 300 fathoms, off the Lofoten Islands, by G. O. Sars, a son of the celebrated Professor of Natural History in the University of Christiania, by whom it was described in the year 1868. It is obviously a form of the Apiocrinidæ still more degraded than Bourguetticrinus, which it closely resembles.

The genus Bathycrinus must also be referred to the Apiocrinidæ, since the lower portion of the head consists of a gradually expanding funnel-shaped piece, which seems to be composed of coalesced upper stem-joints. The stem of Bathycrinus gracilis is long and delicate; in one example of a stem alone, which came up in the same haul with the one nearly perfect specimen which was procured, it was 90 mm. in length.

The general distribution of the deep-sea Asteridea has already been referred to. Perhaps the most obvious peculiarity which they present is the great preponderance of the genera Astrogonium, Archaster, Astropecten, and their allies. Genera belonging to other groups do not apparently become less numerous, for species of Asteracanthion, Cribrella, Asteriscus, and Ophidiaster are as abundant as they are at lesser depths; but as we go down new species with tessellated mailing on the disk and massive marginal plates seem to be perpetually added.

Of the twenty-six Echinoderms dredged from the *Porcupine,* seven—Porocidaris purpurata, Phormosoma placenta, Calveria hystrix, C. fenestrata, Neolampas rostellatus, Pourtalesia jeffreysi, and P. phiale—are forms which have been for the first time brought to light during deep-sea dredging operations, whether on this or on the other side of the Atlantic. There seems little doubt that these must be referred to the abyssal fauna, upon whose confines we are now only beginning to encroach. Three of the most remarkable generic forms—Calveria, Neolampas, and Pourtalesia—have been found by Alexander Agassiz among the results of the deep dredging operations of Count Pourtales in the Strait of Florida, showing a wide lateral distribution, while even a deeper interest attaches to the fact that while one family type, the Echinothuridæ, has been hitherto only known in a fossil state, the entire group finds nearer allies in the extinct faunæ of the chalk or of the earlier Tertiaries than in that of the present period.

Many of the mollusca from the deep water have hitherto been found only in the northern portions of the area examined, and are generally allied to northern forms.

The abyssal mollusca are by no means devoid of color, though, as a rule, they are paler than those from shallow water. Neither are the abyssal mollusca universally destitute of eyes. A new species of Pleurotoma from 2,090 fathoms had a pair of well-developed eyes on short footstalks; and a Fusus from 1,207 fathoms was similarly provided. The presence of organs of sight at these great depths leaves little room to doubt that light must reach even these abysses from some source. From many considerations it can scarcely be sunlight. The whole of the light beyond a certain depth might be due to phosphorescence, which is certainly very general, particularly among the larvæ and young of deep-sea animals.

"THE MIMIC FIRES OF OCEAN"
—G. Clarke Nuttall

NATURE dazzles the eye of man with many wonderful phenomena, but perhaps never more so than when she turns the gloomy night waters of the sea into a sheet of silvery fire. At these times every movement of the wave, every cleavage of the water by oar or prow, reveals in its dark depths a hidden fire which scintillates and sparkles with weird and mysterious light. The spectacle is one of absolute fascination, for the Spirit of Enchantment rests upon the waters and reality becomes fairyland.

The ancients, keenly alive to a sense of the supernatural, saw in this luminosity a manifestation of some unknown power, and wondered; the ignorant read in it a portent of judgment and terror; while in all ages the curious and the searchers after knowledge have speculated as to its cause. But just as Nature has invested its appearance with a halo of mystery, so she has also wrapped in much obscurity its immediate cause; and thus, though in the course of centuries varying suggestions have been put forward, nothing with any finality about it has been arrived at. It was asserted truly that certain fishes were luminous; sharks have glowed and shone, shoals of herrings, pilchards, or mackerel have been moving masses of light, and the fish drawn out of the water have lain in great shining heaps, the glow of which vanished as they dried and died.

Many writers have described the passages of ships through such shoals—the sheet of moving flames—the beautiful pale greenish elf-light that the fish exhibited; while poets have apostrophized the "mimic fires of ocean" and the "lightnings of the wave," and scientists and naturalists have in turn tried to account for their power of luminosity. Some have attributed it to the presence of certain substances of a fatty nature excreted by the fish and adhering to the surface of their bodies; others have declared that it is due to a subtle power of the fish itself—a form in which the energy of life shows itself under certain conditions, just as this energy may be exhibited in heat, or motion, or electricity; others, again, have ascribed it to direct absorption and transmission of the light of the sun, and so on. Many theories have been elaborated, but none convincingly.

But now, it is asserted, the secret is laid bare.

It is wonderful how many secrets the searching light of the Nineteenth Century is claiming to reveal.

It is only lately that any very serious effort has been made to study this phenomenon, but the research has been abundantly rewarded, for it is now pretty certain that the luminosity is due to the presence in the water of various kinds of bacteria.

Now, bacteria are the very smallest living organisms of which we have cognizance. Millions of them can lie on a penny; therefore, to produce the gleaming appearance recognized by us as phosphorescence, they must be present in numbers too enormous even to contemplate with our finite minds. It would be immeasurably easier to reckon with the stars for multitude than with these phosphorescent bacteria. They are colorless, rodlike bodies, only known to us in the land revealed by the highest powers of the microscope, and careful comparison shows minor differences among them. For instance, some of them are capable of independent motion—we can hardly call it swimming—others are non-motile, some are inclosed in a jelly-like covering, others are without this sheath. Their power of motion is probably due to excessively fine hairs at their extremities, which, moving to and fro in the water, act the part of oars. These cilia have not been found in all forms of bacteria which move, but their presence is inferred, since every advance in the study of motile forms increases the number of bacteria which are seen to possess them.

These light-producing bacteria are known as photo-bacteria, and so far some half-dozen varieties have been distinguished and named. The names in such cases are usually either given from the locality of their appearance (thus, photo-bacterium Balticum, found in the Baltic), from their discoverer (for example, photo-bacterium Fischeri, after Professor Fischer), or from some striking attribute (to wit, photo-bacterium phosphorescens, the commonest light-giving species).

A Dutchman named Beyerinck has made a special study of these photo-bacteria, and has experimented with them in a great number of ways to determine, if possible, why they should thus become illuminated, and if the light plays any notable part in their life-history; but his results are, seemingly, all more or less of a negative nature. He can not find that it has any very important function. The breathing of these tiny organisms is not, apparently, in any way bound up with it; their nutrition, growth, and development go on quite well even if they are placed under such conditions that their luminosity is arrested; in no way, indeed, is it a vital process. It only seems to depend on the food which the bacteria feed upon and the presence of oxygen. Given suitable food and plenty of fresh air, and they exhibit their characteristic light; deprive them of one or the other and they no longer shine.

This knowledge helps us to understand, then, the phenomenon of phosphorescence. It is visible only at night because in the full glare of day the greater light overpowers the lesser; it is visible at certain times and seasons because the conditions are such as to evoke it. And what is favorable for the lighting up of a single bacterium is favorable for all; hence the myriad multitudes of infinitesimal units, each set glowing with its tiny light, are sufficient in the sum total to put a whole ocean aflame.

It would, of course, be presumptuous, and doubtless erroneous, to say that all the phosphorescence of the sea is due solely to photo-bacteria; it can only be asserted in the present state of our knowledge that they are certainly responsible for a great share of it. But this wonder of nature must now be regarded as yet another instance of the mighty results accomplished through the agency of the smallest of living things.

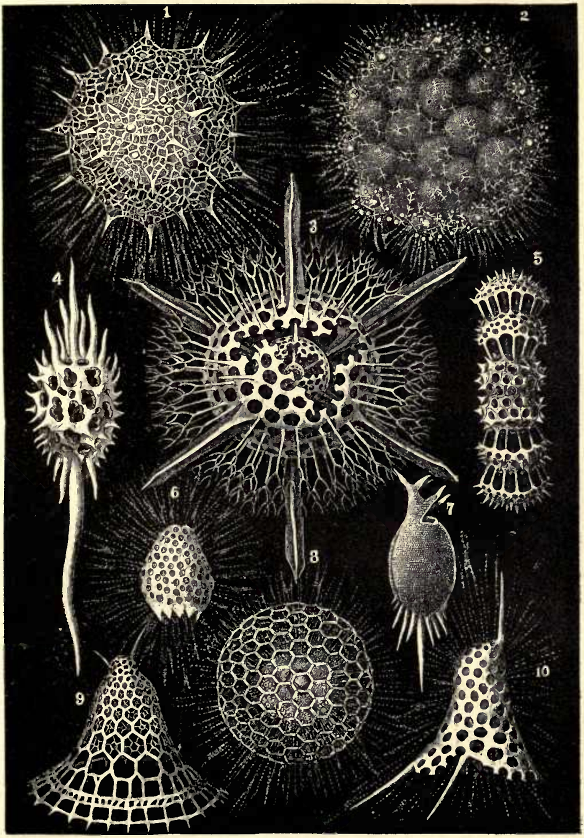
THE JELLY-FISH AND OTHER HYDROZOA.—P. MARTIN DUNCAN

IF anybody were asked to name the commonest objects on a sandy or pebbly seashore, the reply would be—sea-weed, crabs, limpets, a stranded jelly-fish, looking like so much blubber, and a sea-gull flying overhead. The first three things really belong to the shore; the bird is a visitor that is looking after food, and the large, turned-upside-down, basin-shaped, jelly-looking mass is a waif from the ocean. If one of these stranded jelly-fish is looked at, as it lies on the sand, its shape appears to be something like that of an umbrella without the stick. It is thick, however, and has some curious markings about its surface and inside. Even something like a fringe of thick hairs may be detected around the edge. On trying to take it up or turn it over, the fingers go into it, so readily does the animal tear; but on getting the umbrella on its back, the underneath part is seen to be made up, in the middle, of some projections slightly more solid than the rest of the body; and if put between them, the finger passes through a sort of tube into a cavity in the body, which is the stomach.

Some of these jelly-fish, or Medusæ, as they are called, are pounds in weight; but after a while only a shred of membrane-looking stuff remains, the water which makes up nearly all the animal having drained away. It is evident that the large Medusæ grow from small ones, and that there are many kinds of them, some of which are always small. A great jelly-fish, two feet across, was once a little one, leading exactly the same life. They grow, and to grow they must have nourishment; they are never still, and their muscles, transparent as they may be, have to be nourished, or their strength would soon give way. They require not only food, but also air in the water, so that they consume it, and make its oxygen gas of use to them. They seek the light in a remarkable manner, and get out of the way of things very gracefully, and their motions are rhythmical, like the ticks of a clock, in succession. Have they nerves and eyes? Science answers in the affirmative. These creatures, consisting of a vast proportion of sea-water, breathe, digest, and feed. More than this, they produce young; and if they are pale in color, bluish, or roseate in hue during the day, they are the glory of the deep during the night; and each one is a globe of light, the luminousness being the result of the action of the mysterious energy of life upon matter.

Many of the jelly-fish found on the shores dead and injured are eighteen inches across, and it is not uncommon to see one swimming freely whose body is larger than that. Yet in spite of this size, and of the gifts of the creature, it has one of the shortest of lives, and it is born, grown, and dead between the spring and the winter.

On examining a large jelly-fish, it will be noticed to have not only four round bodies on the top, round the centre, and the four lobes hanging down beneath, but that the edges of the body are not quite round, but are notched, so as to make eight lobes to it. And if a little care be taken, marks can be seen on the under part of the body, from the round centre spots to each of the eight splits in the disk; and a magnifying-glass shows a little substance there which feels gritty, and is sometimes colored. Other branching tube-marks pass from the midst of the body to the edge of the umbrella, and a tube runs all round the edge. The tubes communicate in the midst of the body with a cavity, into which the finger can



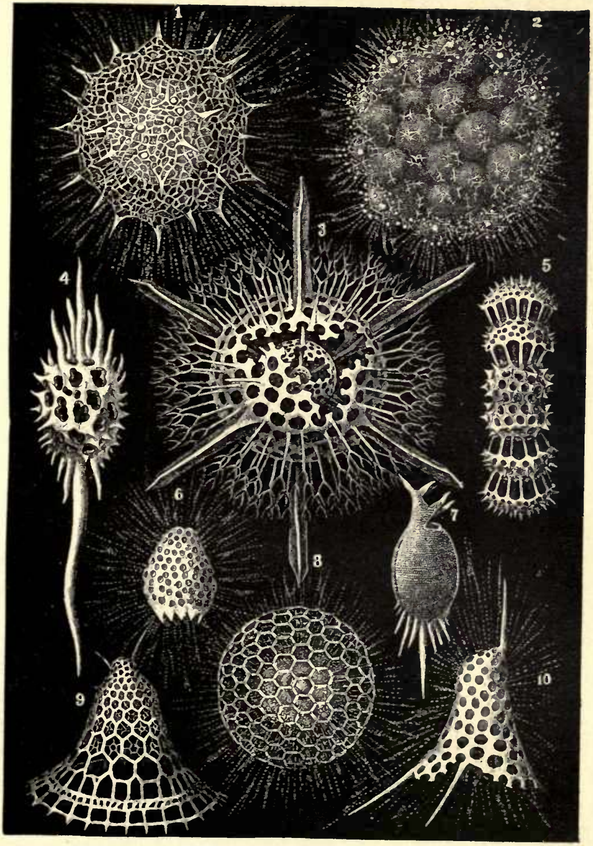
Typical Radiolaria

1, Rhizosphæra; 2, Sphærozoum; 3, Actinomma; 4, Lithomespilus; 5, Ommatocampe; 6, Carpocaium; 7, Challengeron; 8, Heliosphæra; 9, Clathrocyclas; 10, Dictyophimus

pass between the four under lobes—the stomach—and the digested matters pass into them to nourish the creature. Around the disk or umbrella, and outside the circular tube, is the fringe of hairs which have, to a certain extent, to do with the capture of prey. Each consists of a filmy substance, in which are fixed thread-cells, not very unlike those of the sea-anemone, but they have longer barbs and sharper thorns stretching out from them. Any violence or irritation causes the thread to shoot forth and to injure. The rest of the body of the Medusa is covered with an excessively thin skin, which has movable cilia upon it. It is supposed, and with some reason—for nervous threads and bodies have been found on the disk, close to the gritty bodies especially—that these last are eyes, or ears, or both. The nerves supply the muscles that move the umbrella, and cause it to expand and contract, and the muscles are remarkable, for some are not simple contracting fibres all made of one piece, as in the Anemone tribe.

The jelly-fish, when in full vigor and weighing many pounds, must catch and eat much, and the manner in which this is done is by no means perfectly understood. The food is digested, and the results are taken from the stomach into the numerous tubes in the body, where they nourish the tissues. The movements of the animal and its extremely delicate membranes enable much water to come in contact with it, and it breathes by that means, for there are no special gills or lungs.

The four round spots on the top of the body, sometimes white and sometimes red in color, are spaces in the body, and they open into the central stomach. The circles of these chambers are lined with ciliate membrane, and in some places it is arranged in folds, and in them the eggs or ova form. Little oval or roundish things, like pins' heads are they: they burst forth and pass out of the stomach, and then through the canal into the four lobes hanging down like pouting lips. Here they rest a while until a little grown, and they start out on their journey of life in the autumn time as little oval or long things made up of cells, the outside ones having movable hairs also on them. Totally unlike the parent, the tiny offspring floats off with the tide and does a little work in moving itself with its hairy covering. Sooner or later this minute thing, which is called a planula, settles on a stone or piece of sea-weed, and begins to grow. First of all its outer skin is formed into a hollow on the top, a kind of basin-shaped cavity being produced. This is the future stomach. Then some little projections grow around the hollow, and stick out in the water like so many rays, and they increase in number and length very rapidly. Under this shape the creature has been described as a hydra or a polype, and it really resembles a small sea-anemone with very long and slender tentacles. But the internal anatomy differs. The creature is all stomach and tentacles, and it grows by catching small prey. All the elaborate tissues of the jelly-fish are absent and the creature can not move. It is this curious condition of life that brings the jelly-fish tribe within notice of a seashore observer, for those little hydras live in some places at low-water mark. The knowl-



Typical Radiolaria

1, Rhizosphæra; 2, Sphærozoum; 3, Actinomma; 4, Lithomespilus; 5, Ommatocampe; 6, Carpocaium; 7, Challengeron; 8, Heliosphæra; 9, Clathrocyclus; 10, Dictyophimus

edge that the hydra was the child of the jelly-fish was obtained many years ago by a Scotch and by a Scandinavian naturalist. It was known that some small kinds of jelly-fish which were kept in sea-water in an aquarium disappeared altogether in the late autumn. Then it was noticed that there were many very small things with tentacles, on the sides of the glass, which had not been noticed before. And at last the curious discovery was made that these hydras or planulas reproduced jelly-fish the next year. This is a very strange story, and the course of nature's proceeding is, that when food has become scarce and the boisterous waves would become fatal to the delicate Medusa, it shall lay eggs which produce creatures that can settle down out of the way of the rush of water, and that require but little food. Then in the next year when food is in plenty, the progeny separate into jelly-fish like the parent. The hydras or progeny have no power of laying eggs; they digest and produce the creature that shall lay eggs. The Scandinavian naturalists and Germans called this "alternate generation," and named the hydra the nurse of the jelly-fishes. This is the method by which most of the jelly-fish, which may be occasionally seen stranded on the coast, were produced; but there are some whose planulas do not settle down, but are always free swimmers, and they divide into Medusæ in the sea.

This intensely interesting course of life is modified in all the hundreds of kinds of creatures which are connected with the jelly-fish in classification, by their having many structures in common. The creatures thus classified with the jelly-fish are called Hydrozoa, or Water Animals, and they pass two lives, one of which is commonly observed on the seashore everywhere. One life is a fixed one, and the other is a free swimming one; in one stage it is eating and drinking, and in the other, these functions are not always or often carried out. The egg-laying and perpetuation of the animal are the duty of the greater part of the beautiful branched and hair-like things which are arranged by visitors to the seaside in patterns, and retained as memorials of pleasant days, and which are popularly called sea-weeds. They are not such things, but are the delicate stems, branches, and bud-like homes of the parents of tiny jelly-fish, which are only to be caught in the open sea. These horny stems and branches end in creatures with tentacles or feelers, and they live between tides, in rock pools, and at low water.

Sometimes these fragile, plant-looking things are fixed on to stones or sea-weed, and some get a ride by growing on shells, inhabited, since the death of their original possessor, by the Hermit Crab.

One very numerous tribe of these feathery-looking weeds, but which are truly animals, is common everywhere on the shore, between tide-marks into deep water. Their stems are branching, and the little bud-like things on them, when watched in still water, may be seen to put forth pretty colored bodies with tentacles around a centre; and as there may be hundreds of them on the branches and stem, the creature resembles a bunch of rayed flowers. Hence the name Sertularia, from sertula, a small garland.

These Sertularians were noticed and drawn many years ago, and were called Corallines. This is a great mistake, because the Coralline is a plant covered with carbonate of lime. The correct name would be the Garland polypes. When we get a bunch of these creatures from the seaside they are dead, and the hard and preservable outside parts alone are left, all the beauty of color and the wonderful inside structure are gone. But even then it can be noticed that the stems of the creature arise from a network of tubes fixed on to stones, sea-weeds, and shells. This resembles a root, but it does not absorb nourishment like the root of a plant. The stems, often not bigger than hairs, are hollow, and the branches also. The surface of the branches is covered on one, or often on both sides, by minute cups. These give almost a saw-edge look to it, in some of the creatures; and among these cups, which are open at their free end, are some larger ones, which are closed where free, and often ribbed and ornamented on their outside. It is noticed that the hollow of the stem and branches is continued into the cups, but not into the closed ones, and that these are shut off from it by a very delicate layer of tissue. This is the minute structure of these things when dead; but when alive, the inside of the stem and branches is filled with a soft substance, which reaches up to the part where each of the cups is attached to the outside. The cups, hundreds in number, on each stem and branch, contain a most beautiful flower-like polype. Variously colored, according to the kind, it has a bell shape, and has a spot for the mouth, which leads to a stomach, whose floor is connected with the pith of the whole branch. Around the mouth are numerous tentacles excessively irritable, capable of stinging and paralyzing prey; and the spectacle of hosts of these, all working for the common good of the branching animal, is very beautiful. Sometimes there is much red in the color, at other times green, yellow, or a dull tint; and in order to relieve the sameness of outline presented by thousands of cups, their horny margin is spined or toothed. In full vigor during the summer, and living through the winter and probably for several years, these cups with their tentacled polypes contribute to the growth and nutrition of the whole. They all work for a common end, and that is for the persistence of the life of the colony. They live on microscopic things in the water, such as minute ova, or the young of things like unto themselves, and on animalcules, and probably on the moving spores of sea-weeds. As the spring advances, the larger and closed cups begin to grow by budding from the stem, and they become filled with a gummy substance with a few granules in it, and somewhat resembling the pith of the stem. As the closed cup grows, it often becomes marked on the outside with rings or belts, and it becomes a very prominent object on the horny-looking Garland polype. These closed cups are concerned in the reproduction of the creature, for after a few weeks the substance inside them is seen to collect into bunches of round or oval bodies, often yellow in color, or of other tints. By and by the cup bursts, or a sort of trap-door opens at the top, and these things escape. They are small, covered with cilia, or moving hairs, and resemble the planulas of the jelly-fish in shape, and they swim freely, and finally settle down on a stone or weed. They become environed by a horny coat, the stomach having been formed first by simple bending in of the outside of the creature, and tentacles grow. The planula thus founds a new colony. But there are other phases in this curious life-story; for instead of the little round balls in the closed cups getting free as planulas, some in certain kinds grow there, and resemble excessively minute jelly-fish stuck fast by the back, and exposing the mouth, feet, and the fringed umbrella. These Medusæ, as they may be called, die on the parent, and never wander.

There is one kind of these Garland polypes called Lafœa in which the round bodies produced in the closed cups burst forth, and not in the shape of planulas. They come forth like tiny bells, furnished with minute eye-spots on the edge, and they have an umbrella shape, and long tentacles arising from the edge near the eye-spots. They are jelly-fish, to all intents and purposes, and swim freely about, and in time produce planulas which develop into a parent Garland polype again.

There is a very interesting kind of these allies of the sea-jellies which, from its feathery shape, has been called Plumularia. Specimens are common, and there is a stem, and it has branches, and the cups are in one row on the branchlets. Moreover, there are openings in the horny envelope of the soft pith of the branches, which do not give exit to a polype-looking thing with its mouth surrounded with tentacles, but to a simple pith with many threads or stinging cells in it. It is more or less like a long tongue, and is placed among the cups with polypes, and it is evidently an instrument for capturing minute creatures. The Sickle-beard is one of them.

But one of the most singular of these delicate creatures lives in very numerous colonies, on such an unexpected place as the outside of the shell tenanted within by a wandering hermit-crab. It is called Hydractinia. The Hydractinia has a kind of crust for its formation, with tubes in it, and out from them comes a white film, which, under a magnifying-glass, presents a number of stems and polypes. Each one has at its free part a club-shaped end, which has several rows of tentacles around it. These, often twenty-five in number, are, like the stem, very irritable, flexible, and are covered with a sticky matter. The club is hollow within, for the stomach, and food gets in by the top, where the horny skin appears to be absent.

The tentacles are rather sharp, and when they are half-contracted they often appear to have a knob at the end, otherwise they are stuck out and are like so many thick threads. The stalk which supports the conical-shaped head has a thin and wrinkled skin with sharp, dot-like points on it, and probably they secrete a sticky substance. The polypes thus formed cluster together like so much moss on the shell, and it would appear, if not in the English species, certainly in one which frequents the American coasts, that some groups are male and others female. But there is no doubt, from the researches of Mr. Moseley, F.R.S., of the *Challenger,* that some of the polypes act as catchers of food, and feed those which pay especial attention to increasing and multiplying. These last have minute little knobs growing on the stalk beneath the head, and which develop round bodies inside. After a while motion is noticed in them, and there is every reason to believe that they burst forth and swim off as small jelly-fish. Some, however, give out little planulas, which settle down and grow like the parent.

It will have been noticed from this description that these polypes are different in shape from the Garland polypes and that instead of being bell-shaped, with tentacles around the mouth, they are club-shaped, and have more than one row of tentacles half way down. This last shape gives a characteristic to many little polypes which lead, like the others, two lives—one fixed on the seashore on plants and stones, and the other, freely swimming, as a pretty little jelly-fish.

Another kind lives fixed on sea-weeds in shallow water, and its stem consists of a single tube, which is creeping and threadlike. The cups for the polype are on long stalks, with markings like rings on them, and are bell-shaped with a toothed edge. The mouth is surrounded by tentacles, as in the Garland polype, and, in fact, there is not much outside distinction between them and this Campanularia, or Bell polype.

There is a stomach in the polype bud which leads to a canal that goes down the stalk, and even into the creeping stem or root. The buds, on stalks of their own, are very remarkable. They contain, soon after they are formed, numerous little jelly-fish attached to stalks. There may be twenty or thirty of these in each bud, and the day will come when they will burst forth, be cast loose from their stems, and swim off. They resemble hand-bells of a very flat kind, and the mouth is prolonged into a four-parted projection, which protrudes through a structure not seen in the great jelly-fish, but peculiar to these smaller ones, which fills up the disk underneath, from the mouth to the edge, with a layer of muscular fibres. They have four long tentacles, and when they have lived for some time they begin to play some very curious tricks. Thus a foreign naturalist, M. Van Beneden, was examining some creatures in his aquarium, and found hundreds of these very small jelly-fish, and he caught some in order to examine them with his microscope. He began to draw some of them carefully in order to write a description of them. About an hour afterward, on again looking at his specimen, he was amazed to find its shape changed, and the animal apparently turned inside out. The tentacles on the edge seemed to be reversed in their position; the umbrella-like dome, from being convex was the reverse. and the curled lip-like proboscis seemed converted into the stem of a solitary polype. One of these Campanularians, called erroneously the Wrinkled-thread Coralline, grows on sea-weeds near low-water mark, and especially on the great Riband Tangle. It is a small thing, about an inch in height, and its stem is of a pink or rose-red color; it is sparingly branched in a zigzag manner, and its stem is ringed. The buds develop jelly-fish, but they never escape, and hang on by stalks for the rest of their lives.

FISHES.—ANDREW WILSON

THIS division every one must know as that of the Vertebrata, a word which may be used in a popular sense, as corresponding to the expression "backboned" animals. At the head of this group man and quadrupeds are found, while the fishes form the lowest class in the division.

There are few groups of the animal world more interesting to the ordinary observer than that of the fishes. To survey the various forms and shapes presented by these animals as displayed in a great museum should prove a sufficient incentive to gain a more intimate acquaintance with the class; and when, even in a popular sense, we investigate the structure and habits of fishes, the study increases in its fascination and interest. While if we reflect that on a knowledge of the habits of fishes, of their distribution in our oceans and seas, and of the special products which many of them offer for our use and luxury, the commercial success of our fisheries depends, it can need no further argument to convince us that, after all, there is something of great practical benefit to be derived from the study of zoological science.

It is not our intention at present to say anything regarding the commercial or economic aspects of fishes, and even their general habits must be very briefly touched upon. We rather aim at giving some account of the structure of the fishes, and at noting such peculiarities in their habits and life as may prove most interesting to our readers. Primarily, then, we find that fishes may be recognized by having the body usually, but not always, covered with *scales,* of various forms and kinds. Then, secondly, we have the limbs represented by certain *fins;* and, thirdly, we find almost all fishes to breathe by *gills* during the whole of life. These three points are, in the main, sufficient to distinguish fishes from their higher as well as their lower neighbors. The scales which cover the bodies of fishes present great diversities in shape, size, and appearance. Some fishes thus exhibit an utter want of scales; while others, like knights of old, are incased in a veritable suit of scaly armor. The lampreys, and their curious neighbors the hag-fishes, are destitute of scales; and in our familiar eels, the scales are very small and insignificant. Such fishes, however, are amply compensated for the want of scales by the power they possess of throwing out from the skin a vast quantity of glutinous or oily matter, technically named *mucus.* The presence of this secretion, which has given origin to the phrase "as slippery as an eel," serves to protect the surface of the body, and no doubt also assists in the easy progress of these fishes through the water. So large is the quantity of this oily matter which the hag-fishes can emit from their body, that one form has received the specific name of glutinosa; the fish being able in this way to literally convert the water of the vessel in which it is contained into a jelly-like mass. The familiar blennies, found in rock-pools after the tide has receded, are also able to emit a large amount of this glutinous fluid.

Illustrating the opposite extreme of the development of scales, we find such fishes as the bony pikes of North American lakes and rivers, the bodies of which are covered with an armor of closely fitting and overlapping scales or plates, named ganoid, from their shining appearance (Greek *ganos,* splendor). The scales of this fish are said to be employed in the manufacture of the little "mother-of-pearl" buttons, so commonly used. Many fossil fishes were also abundantly provided with these hard, bony plates; and our living sturgeons possess scales of similar nature, although in the latter fishes they do not completely cover the body. The bright silvery scales of the herring and its neighbors are thin structures, and are very easily detached from the skin; and a curious form of scale is seen in the perches; the hinder edge of each scale in the latter case being cut into comb-like teeth. In the sharks, skates, and rays, the scales are small and horny, and are often provided with little spines. If we draw our hand along the back of a dog-fish from tail to head, as when we stroke a cat's back the wrong way, we feel numerous small projecting points, borne on the scales. The rough skin surface thus produced is frequently used under the name of "shagreen" in the manufacture of spectacle-cases and like articles, and is also employed for polishing the surface of wood.

In their general shape the bodies of fishes exhibit a great compression from side to side, a rounding of the sides, and a pointing of either extremity, adapting the animals for easy progression through the water. Some fishes, such as the soles, flounders, plaice, etc., are named "flat fishes" from the great flattening exhibited by their bodies; although, at the same time, it is important to observe that these fishes are simply more compressed from side to side than their neighbors. Most persons, on looking at a sole or flounder, are apt to think that one of the flat surfaces must represent the back, and the other the under surface of the body. This idea is strengthened by the fact that the so-called back surface is dark, and the apparent under surface light in color, and because both eyes exist on the dark-colored surface. That, however, the flat surfaces are really the *sides* of the fish may be seen by noting that on each surface a breast-fin is developed; these fins being placed invariably one on each side of the body. And while the eyes in early life are disposed one on each side of the head, in the position in which eyes are naturally situated, they are gradually brought round to one side by the bones of the head becoming curiously twisted in the course of development. Thus these fishes lie and swim on one side—that which is light-colored—and present a most singular combination of curious and abnormal features.

The fins of fishes constitute interesting features in their structure. Almost all fishes have two sets of fins—those which exist in pairs and those which are unpaired, and which are developed in the middle line of the body. To the former class belong the two pectoral or "breast-fins" and the two ventral or "bellyfins." The "breast-fins" correspond to the forelegs of other animals or to the arms of man; while the ventral fins correspond to the hindlegs or to man's lower limbs; and these latter fins may be placed, as hind-limbs should be, to the rear of the body (as in sturgeons); or they may be found (as in the cod) placed beneath the breast-fins on the throat.

It may be asked, How do we know that these two pairs of fins represent the limbs of other animals? We reply, because when we investigate their structure we find them to be supported by a bony skeleton, the various portions of which correspond to those existing in the skeleton of the limbs of man or other vertebrates. And it is only through this important principle of tracing out what are known as the homologies or resemblances between parts, and by looking at and comparing their structure, that we are enabled to find out the real nature of many organs in animals; similar organs frequently existing under very different and varied guises.

The other fins of fishes do not exist in pairs, but are placed in the middle line of the body. Hence they are named the median or unpaired fins. Thus we find the back or dorsal fins to represent the unpaired fins, as also do the tail and anal fins; the latter being placed on the lower surface of the body. These unpaired fins, if they correspond to any other structures in the fishes, are simply to be regarded as special developments of the skin, and therefore bear no true relationship to the limbs of other animals. We may find one or more dorsal and one or more anal fins; but the tail-fin, by the action of which, as every one knows, the fish chiefly swims, is always single, but may be divided into halves. Most of our common fishes have the halves of the tail-fin of equal size; others, such as the sharks, sturgeons, etc., having the upper half greatly exceeding the lower half of the tail-fin in size. In one species of shark, named the Thresher or Fox-shark, the upper half of the tail-fin appears enormously developed as compared with the lower half; and the names of this species have been derived from the use the fish makes of its tail in lashing the water, and from the long-tailed appearance suggesting a resemblance to the familiar Reynard of the land. In fishes the tail-fin is always placed vertically, or in the same line as the body, and moves from side to side; while in the whales—which are not fishes, but Mammalia or quadrupeds possessing fish-like bodies—the tail-fin is placed across the body. Some fishes may want arms or legs—that is, the pectoral or ventral fins; the eels, for example, possessing no ventral fins. The flying-fishes, on the contrary, possess a very large development of the pectoral or breast fins, and support themselves temporarily in the air by their aid.

Fishes are usually very well provided in the matter of teeth. What would be thought of a quadruped which had teeth not only in its jaws, but had its tongue, its palate, the sides and floor of its mouth, and other parts, also bearing rows of these structures? Yet such is the case with many fishes. Then, also, where the teeth of one set in fishes are lost, or destroyed through the natural wear and tear to which they are subjected, new teeth are developed to supply the place of the lost members. Any one may gain a good idea of the formidable array of teeth in fishes, and of the manner in which one set succeeds another, by inspecting the jaws of a shark in a museum. In fishes the teeth are not implanted in sockets, but are fastened by ligaments to the surface of the bones which bear them. Sometimes one tooth only is developed in fishes. This is the case in the curious, eel-like hag-fishes already mentioned; these fishes possessing but a single large tooth, borne on the palate; and by means of this formidable weapon, which possesses saw-like edges, they bore their way into the bodies of other fishes, and there take up their abode as unwelcome guests. A cod or large haddock may sometimes be found with five or six hags contained in its interior. The parrot-fishes, or Scari, of tropical seas, are so named from their possessing jaws shaped like the beaks of those familiar birds, and these jaws are rendered all the more extraordinary from their being covered or incrusted by numerous small teeth, which are as closely packed on the jaw as paving-stones are in a street, and which serve these fishes as useful instruments when they feed upon the living parts of the hard and limy coral-animals. In the jaws and floor of the mouth of the Port Jackson shark, or in the Eagle rays, or skates, the teeth may be seen to be flat and broad. Such teeth form a regular pavement arranged like a mosaic pattern, and are admirably adapted for crushing whatever substances enter the mouth.

Fishes are well provided in the way of digestive apparatus. A throat or gullet, stomach, intestines, liver, and other glands, serve for the digestion of the food, and a heart and blood-vessels exist for the circulation of the blood thus manufactured from the food. The blood is purified in the gills. Each gill —consisting in common fishes of a supporting "arch" bearing a great number of delicate filaments arranged like the teeth of a comb—may be viewed as simply a network of blood-vessels. The blood, pumped into this network by the heart, is purified by the action of the oxygen gas contained in the pure water which the fish is constantly taking into its gill-chamber by its mouth; while the pure blood is recirculated through the body, and the water used in breathing is got rid of by being ejected behind the "gill-cover" at the neck, so as to allow a fresh inflow to be drawn in by the mouth. The gills of some fishes may be very differently constructed from those of the common members of the class. Thus the lampreys breathe by pouch-like gills which open each by a separate aperture. Seven gill-apertures may be seen on each side of the neck of the common lamprey; and the sharks, skates, and their neighbors also breathe by sac-like gills. Certain curious facts regarding the breathing of fishes will be afterward alluded to. Fishes illustrate plainly what is meant by aquatic or water-breathing. They possess gills or organs, adapted for separating the atmospheric air which is entangled or contained in the water; land-animals breathing the same air directly from the atmosphere.

That fishes are wary and active, and possess senses of acute nature, are facts well known to all. The lowest fish, the little clear-bodied lancelet, possesses no brain whatever, and no organ of hearing is developed, while the eyes are at the best of very simple and rudimentary structure. In other fishes, again, the brain and nervous system not only acquire a typical development, but the senses also advance in perfection. The sense of sight is of perfect kind, the eyes of fishes being adapted for seeing in the dense medium in which they live; while the sense of smell is also developed, although, curiously enough, the nostrils, in all except two kinds of fishes—the hag-fishes and the curious Lepidosiren or mud-fish—are pocket-like in nature, and do not open backward, as in higher animals, into the mouth. The sense of taste is not exercised in a high degree by fishes, and it is interesting to observe that the sense of touch appears to reside especially in the sides of the body, on which surfaces a well-marked line—the "lateral line"—may be observed in most fishes. This lateral line is connected with a series of canals or sacs abundantly supplied with nerves. The function of these organs is believed to be that of exercising the sense of touch; and from the manner in which many fishes swim against objects, and bring the sides of their bodies in gentle contact with foreign objects, there would seem to exist strong reasons for supporting the above idea. That fishes "hear" is a well-known fact. No outer ear is developed, but an internal ear—the essential part of the organ of hearing—is found in all fishes except the little lancelet.

While the intelligence or instinct of fishes is not, generally speaking, of a high order, there are not wanting instances to prove that these animals may exhibit traits of character sometimes wanting in higher groups of animals. Any one who has kept gold-fishes must have noted that in time they become more and more familiar with the hand that feeds them, and the experience of aquarium keepers goes to prove that some fishes may even show signs of recognizing friends.

Like the human race, the class of fishes evinces many illustrations of individuals and groups which differ more or less widely from their more commonplace neighbors. To some of the more curious of these "odd fishes" we may next direct attention.

A very singular little group of fishes, for example, is that known to the naturalist by the name Lophobranchii; this term meaning literally "tuft-gilled." Included in this division are two curious families, of one of which the sea-horses or Hippocampi are the representatives; while to the other family belong their allies, the pipe-fishes. No more interesting forms than these two groups can well be selected from the great class of which they are little-known members. And the interest with which they are regarded by zoologists extends beyond the mere investigation of their outside form or appearance; since they present, in many points of their economy, and habits, very marked deviations from what one may call the ordinary course of fish-life.

Imagine a little body from four to six inches in length, topped by a head which in outline exactly resembles that of a horse, and which tapers off below, or rather behind, into a lithe, flexible, and pointed tail, and we may form a rough idea of the general appearance of one of the sea-horses. This little body we shall find to be covered with ganoid plates or scales of hard horny or bony material, exhibiting ridges and angles all over its surface. Two large brilliant eyes, each of which may be moved independently of the other, add to the curious appearance of the head; while to the body itself may be attached long streamers of sea-weed, serving to conceal the little beings as they nestle amid their marine bowers, each looking like some veritable creation of heraldic or mythological kind.

The flexible tail which terminates the body has the important office of mooring or attaching the fishes to any fixed object. As we see them in the aquarium, they are generally poised, as it were, on the tail; the latter being coiled around a bit of sea-weed, while the erect body and head look warily through the waters of their miniature sea. When they detach themselves, they swim about in the erect position by means of the two pectoral or breast fins, which being placed close to the sides of the neck, project like veritable ears, and assist in rendering the equine appearance of the head of still more realistic nature. These fins move with a quick twittering motion, and propel their possessor swiftly through the water; while the back-fin, placed toward the hinder extremity of the body, also assists them in swimming.

Some curious points in the internal structure of the sea-horses warrant a brief notice. As already stated, the gills of an ordinary fish are shaped each like a comb; the teeth of the comb being represented by the delicate processes, each consisting in reality of a network of blood-vessels, in which the blood is exposed to the oxygen of the water, and is thus purified. In the sea-horses, however, the gills do not present this comb-like appearance, but exist in the form of separated tufts or bunches of delicate filaments, which spring from the gill-supports or arches. From this peculiarity the name "tuft-gilled," already alluded to, is derived, and the pipe-fishes agree in the structure of the gills with the sea-horses. Then, also, as most readers are aware, the gills of ordinary fishes are covered by a horny plate, appropriately named the gill-cover, and it is by sharply compressing the gills with this cover that the water used in breathing is ejected from the gills, so as to make room for a fresh supply. In the sea-horses, however, the gill-cover is not open or free at its under and hinder edges, but is firmly attached all round to the neighboring tissues, and so rendered immovable. At one point in its circumference, however, a small aperture is left, through which the breathing-water escapes from the gills.

The sea-horses are found abundantly in the English Channel, around the coasts of France and Spain, in the Mediterranean Sea, and in the tropical oceans. Several distinct species are known to zoologists, but they closely resemble one another in the essential features just noted. They are lively and intelligent little creatures, and become familiar in time with their possessors. Fixed by their tails, they may be seen actively to dart the head at any passing object adapted for food; while, when they wish to free their bodies from the attached position, they appear to manœuvre with the chin and head in order to effect their purpose. Their food appears to consist of small crustaceans, worms, etc.; and they are known to be especially fond of such delicate titbits as are afforded by the eggs of other fishes.

Perhaps the most curious part of the history of the sea-horses relates to their care of the young. Fishes generally take little or no care of their offspring, and it is therefore the more surprising to encounter in these little beings a singular example of parental fidelity and attachment. Nor, as might be expected, is it the mother-fish who is charged with the task of attending the young. Contrary to the general rule, the male fish assumes the part of nurse, and well and faithfully does he appear to discharge his duties. At the root of the tail in the male sea-horse a curious little pouch is seen. In this pouch the eggs laid by the females—which want the pouch—are deposited, and are therein duly hatched. Nor does the parental duty end here; for after the young are hatched and swim about by themselves, they seek refuge in the pouch during the early or infantile period of their life whenever danger threatens them. This procedure forcibly reminds one of the analogous habits of the kangaroos and their young; but the occurrence is the more remarkable in the lower and presumably less intelligent fish.

Some experiments made on the sea-horses seem to demonstrate the existence of a more than ordinary degree of attachment to the young. Thus when a parent-fish was taken out of the water, the young escaped from the pouch; but on the parent being held over the side of the boat, the young at once swam toward him, and re-entered the pouch without hesitation. Some authorities have not hesitated to express an opinion that the young are nourished within the pouch by some fluid or secretion of its lining membrane. But further observation is certainly necessary before this latter opinion can be relied upon.

The pipe-fishes are very near neighbors of the sea-horses, and derive their name from the thin elongated shape of their bodies, together with the fact that the jaws are prolonged to form a long pipe-like snout, at the extremity of which the mouth opens. These fishes are very lively in all their movements, and dart through the water so quickly that in many cases the eye is unable to follow them. Like the sea-horses, the male pipe-fishes protect and tend their progeny, and exhibit an equal attachment to their young.

These latter features are also well exemplified by the familiar sticklebacks of our ponds and streams. The latter fishes actually build nests for the reception and care of their eggs, the nests being made chiefly or solely by the males; while on the latter, during the process of hatching and in the upbringing of the young, devolves the chief care of protecting and looking after the welfare of the progeny. These instances of the care and duties which devolve on the males, instead of on the mother-parents, appear to reverse the more natural order which almost universally obtains in the case of both lower and higher animals.

Of the oddities which fish-life presents, probably none are more remarkable than the archer or shooter fishes (Toxotes), which inhabit the seas of Japan and of the Eastern Archipelago. When kept in confinement, these fishes may be seen to shoot drops of water from their elongated jaws at flies and other insects which attract their attention. They have been observed to strike their prey with unerring aim at distances of three or four feet. Another notable species of shooting-fishes is the Chætodon. This latter form possesses a prominent beak or muzzle, consisting of the elongated jaws; and from this beak, as from the barrel of a rifle, the fish shoots its watery missiles at the insects which alight on the vegetation fringing its native waters.

The old saying which compares great helplessness to the state of a "fish out of water" does not always find a corroborative re-echo in natural history science. As every one knows, different fishes exhibit very varying degrees of tenacity to life when removed from their native element. Thus a herring dies almost immediately on being taken out of water; while, on the other hand, the slippery eels will bear removal from their habitat for twenty-four hours or longer; and we have known of blennies—such as the shanny (Blennius pholis)—surviving a long journey by post of some forty-eight hours' duration, when packed amid some damp sea-weed in a box.

But certain fishes are known not merely to live when taken out of water, but actually of themselves, and as part of their life and habits, to voluntarily leave the water and disport themselves on land. Of such abnormal fishes, the most famous is the climbing perch or Anabas scandens of India, which inhabits the Ganges, and is also found in other Asiatic ponds and rivers. These fishes may be seen to leave the water and to make their way overland, supporting themselves in their jerking gait by means of their strong spiny fins. They appear to migrate from one pool to another in search of "pastures new," especially in the dry season, and when the water of their habitats becomes shallow.

The Hindu name applied to these fishes means "climbers of trees"; and although statements have been made both by travelers and natives that the climbing perch has been found scaling the stems of trees, these accounts, we fear, must be regarded as of equal value with the native belief that the fishes fall in showers on the land from the skies. Of the power of the fishes to live for five or six days out of water, however, no doubt can be entertained; and their ability to support life under these unwonted conditions is explained by the fact that certain bones of the head are curiously contorted so as to form a labyrinth, amid the delicate recesses of which a supply of water is retained, for the purpose of keeping the gills moist.

Another group of fishes, also inhabiting India, and possessing powers of existing "out of water," is the Ophiocephalidæ ("snake-headed"); a family allied to the Mullet group. It would appear, from some observations on these fishes, that they are enabled not only to live, like the climbing perch, out of water, but that they die if kept below the surface of the water even for a comparatively short time. Thus when an Ophiocephalus and a carp were placed together in a vessel of water, a net being placed about two inches from the surface, the carp swam, as might be expected, freely and continuously below the surface, while the Ophiocephalus made vigorous efforts to attain the surface, for the purpose of inhaling air directly from the atmosphere. When not allowed to reach the surface, the Ophiocephali died, suffocated, in periods varying from twenty minutes to two hours. The explanation of the power possessed by the latter fish, of being able to live out of water, resides in the fact that these fishes possess two cavities in the throat, in which blood is purified by the inhalation of atmospheric air. Thus the Ophiocephalus not only can exist out of water, but escape from that medium must, in fact, be viewed as an absolute necessity for the normal life of the animal. The climbing perch appears also to exhibit this latter peculiarity of requiring to escape periodically from the water, for this fish, like the Ophiocephalus, may be actually drowned, if kept from obtaining a supply of atmospheric air.

The curious Lepidosirens or mud-fishes, which occur in the Gambia of Africa and the Amazon of South America, exhibit a greater peculiarity of structure, which still more completely fits them for living out of water. In the great majority of fishes, a curious sac or bag known as the *swimming* or *air bladder* is found. The use of this structure in ordinary fishes is to alter the specific gravity of the animals; and, by the compression or expansion of the air or gases it contains, to enable them to sink or rise in the water at will; but it would also appear that indirectly it may aid in the breathing of all fishes which possess the organ. In the mud-fishes, however, the air-bladder becomes divided externally into two sacs, while internally each sac exhibits a cellular structure resembling that seen in the lungs of higher animals, with which structures, in fact, the swimming-bladder of fishes actually corresponds. Then also this elaborate air-bladder of the mud-fish communicates with the mouth and throat by a tube, which corresponds to a windpipe. The nostrils of the mud-fishes further open backward into the mouth; while, as already mentioned, in all other fishes, save one genus, the nostrils are simple, closed, pocket-like cavities. And it may lastly be noted that the Lepidosirens are in addition provided with true gills, like their ordinary and more commonplace neighbors.

These remarks serve to explain the "reason why" these fishes can exist for months out of water. Thus, on the approach of the hot season, the mud-fishes leave their watery homes and wriggle into the soft mud of their native rivers. Here they burrow out a kind of nest, coiling head and tail together; and as the mud dries and hardens, the fishes remain in this temporary tomb; breathing throughout the warm season like true land-dwellers, by means of the lung-like air-bladder. When the wet season once more returns, the fishes are aroused from their semi-torpid state by the early rains moistening the surrounding clay; and when the pools and rivers once more attain their wonted depth, the Lepidosirens emerge from their nests, seek the water, breathe by means of their gills, and otherwise lead a true aquatic existence. Another fish, the Ceratodus or "Barramunda" of Australian rivers, possesses a similarly modified air-bladder, and is thus enabled to breathe independently of its gills.

With such a combination of the characters of land and water animals, it is little to be wondered at that the true position of the mud-fishes and their neighbors in the zoological scale should have formed a subject for much discussion. They appear, however, to be true fishes, and not amphibians (or frog-like animals); and they therefore may legally occupy a prominent position among the oddities of their class.

Other curious beings included among the fishes are the so-called globe-fishes (Diodon, etc.), which derive their name from their power of distending their bodies with air at will; and their bodies being usually provided with spines, they may be judged to present a rather formidable front to any ordinary adversary in their expanded condition. Then also we have the curious trigger-fishes (Balistes), so named from the prominent pointed spine in front of the first back-fin; this spine firmly holding its erect position until the second spine or fin-ray be depressed, when the first spine is released by mechanism resembling that of the trigger of a gun. The obvious use of such an apparatus is clearly of a defensive kind; and it is remarkable to find that man has imitated and reproduced, in one of his common mechanical contrivances, a structure existing in all its natural perfection in the fish.

Oddities in the way of curious fishes can receive no better illustration than that afforded by the very curious "telescope-fishes" of China. These beautiful little fishes are kept alive in many of our large aquaria. At first sight the telescope-fishes might be mistaken for the familiar gold-fishes, but a cursory inspection of their appearance at once shows the peculiarities of structure which have earned for these creatures their distinctive name. The eyes are seen to be singularly prominent, and protrude from the head to a marked extent, while they also present certain alterations in intimate structure. The fins, moreover, are double, this conformation being well exemplified in the large and prominent tail-fin. The exact nature of these fishes has been discussed by the French Academy of Sciences, in the records of which it is stated that the Chinese have cultivated these fishes from an ordinary species of the carp race, and that the peculiar conformation of the eyes results from a diseased state, which, by being transmitted from one generation to another, has become at last a stable and definite character of the animals. This very probable explanation of the origin of these peculiar eyes is supported by the fact that certain carps inhabiting the canal Saint Martin at Paris were found to possess prominent eyes; and a like appearance has been observed in carps living in rivers into which the water of drains had been allowed to flow.

WONDERS OF THE SHORE
—CHARLES KINGSLEY

SEE, on the shore, a shell bed, quite large, but comely enough to please any eye. What a variety of colors and forms are there, amid the purple and olive wreaths of wrack, and bladder-weed, and tangle (ore-weed they call it in the south), and the delicate green ribbons of the Zostera (the only English flowering plant which grows beneath the sea). What are they all? What are the long, white razors? What are the delicate green-gray cimeters? What are the tapering brown spires? What the tufts of delicate yellow plants like squirrels' tails and lobsters' horns, and tamarisks, and fir-trees, and all other finely cut animal and vegetable forms? What are the groups of gray bladders, with something like a little bud at the tip? What are the hundreds of little pink-striped pears? What those tiny babies' heads covered with gray prickles instead of hair? The great red starfish, which the Ulster children call "the bad man's hands"; and the great whelks, which the youth of Musselburgh know as roaring buckies, these we have seen before; but what, oh what, are the red capsicums?

Yes, what are the red capsicums? and why are they poking, snapping, starting, crawling, tumbling wildly over each other, rattling about the huge mahogany cockles, as big as a child's two fists, out of which they are protruded? Mark them well, for you will perhaps never see them again.

That red capsicum is the foot of the animal contained in the cockle-shell. By its aid it crawls, leaps, and burrows in the sand, where it lies drinking in the salt water through one of its siphons and discharging it again through the other. Put the shell into a rock pool, or a basin of water, and you will see the siphons clearly. But I suppose your eyes will be rather attracted by that scarlet and orange foot which is being drawn in and thrust out to a length of nearly four inches, striking with its point against any opposing object, and sending the whole shell backward with a jerk. The point, you see, is sharp and tongue-like, only flattened, not horizontally, like a tongue, but perpendicularly, so as to form, as it was intended, a perfect sand-plow, by which the animal can move at will either above or below the surface of the sand.

Enough of Cardium tuberculatum. Now for the other animals of the heap; and first, for those long, white razors. They, as well as the gray cimeters, are solens, razor-fish (Solen siliqua and S. ensis), burrowers in the sand by that foot which protrudes from one end, nimble in escaping from the Torquay boys, whom you will see boring for them with a long iron screw on the sands at low tide. They are very good to eat, these razor-fish; at least for those who so think them; and abound in millions upon all our sandy shores.

Now for the tapering brown spires. They are Turritellæ, snail-like animals (though the form of the shell is different), who crawl and browze by thousands on the beds of Zostera, or grass wrack, which you see thrown about on the beach, and which grows naturally in two or three fathoms of water. Stay: here is one which is "more than itself." On its back is mounted a cluster of barnacles (Balanus Porcatus), of the same family as those which stud the tide-rocks in millions, scratching the legs of hapless bathers. Look at the mouth of the shell; a long gray worm protrudes from it, which is not the rightful inhabitant. He is dead long since, and his place has been occupied by one Sipunculus Bernhardi, a wight of low degree who connects "radiate" with annulate forms—in plain English, sea-cucumbers with sea-worms. But however low in the scale of comparative anatomy, he has wit enough to take care of himself; mean, ugly, little worm as he seems. For, finding the mouth of the Turritella too big for him, he has plastered it up with sand and mud (Heaven alone knows how), just as a wry-neck plasters up a hole in an apple tree when she intends to build therein, and has left only a round hole, out of which he can poke his proboscis. A curious thing is this proboscis, when seen through the magnifier. You perceive a ring of tentacles round the mouth, for picking up I know not what; and you will perceive, too, if you watch it, that when he draws it in, he turns mouth, tentacles, and all inward, and so down into his stomach, just as if you were to turn the finger of a glove inward from the tip till it passed into the hand; and so performs, every time he eats, the clown's as yet ideal feat of jumping down his own throat.

So much have we seen on one little shell. But there is more to see close to it. Those yellow plants which I likened to squirrels' tails and lobsters' horns, and what not, are zoophytes of different kinds. Here is Sertularia argentea (true squirrel's tail); here S. filicula, as delicate as tangled threads of glass; here abietina; here rosacea. The lobsters' horns are Antennaria antennina; and mingled with them are Plumulariæ, always to be distinguished from Sertulariæ by polypes growing on one side of the branch, and not on both. Here is falcata, with its roots twisted round a sea-weed. Here is cristata, on the same weed; and here is a piece of the beautiful myriophyllum, which has been battered in its long journey out of the deep water about the ore rock. Here are Flustræ, or sea-mats. This, which smells very like Verbena, is Flustra coriacea. That scurf on the frond of ore-weed is F. lineata. The glass bells twined about this Sertularia are Campanularia syringa; and here is a tiny plant of Cellularia ciliata. Look at it through the field-glass; for it is truly wonderful. Each polype cell is edged with whip-like spines, and on the back of some of them is—what is it but a live vulture's head, snapping and snapping—what for?

Next, what are the striped pears? They are sea-anemones, Sagartia viduata, the snake-locked anemone. They have been washed off the loose stones to which they usually adhere by the pitiless roll of the ground-swell; however, they are not so far gone but that if you take one of them home and put it in a jar of water, it will expand into a delicate compound flower, which can neither be described nor painted, of long pellucid tentacles, hanging like a thin, bluish cloud over a disk of mottled brown and gray. Here, adhering to this large whelk, is another, but far larger and coarser. It is Sagartia parasitica, one of our largest British species; and most singular in this, that it is almost always (in Torbay at least) found adhering to a whelk: but never to a live one; and for this reason. The live whelk (as you may see for yourself when the tide is out) burrows in the sand in chase of hapless bivalve shells, which he bores through with his sharp tongue (always, cunning fellow, close to the hinge where the fish is), and then sucks out their life. Now, if the anemone stuck to him, it would be carried under the sand daily, to its own disgust. It prefers, therefore, the dead whelk, inhabited by a soldier crab, Pagurus Bernhardi, of which you may find a dozen anywhere as the tide goes out; and travels about at the crab's expense, sharing with him the offal which is his food. Note, moreover, that the soldier crab is the most hasty and blundering of marine animals, as active as a monkey, and as subject to panics as a horse; wherefore the poor anemone on his back must have a hard life of it; being knocked about against rocks and shells, without warning, from morn to night and night to morn. Against which danger, kind Nature, ever *maximus in minimis,* has provided by fitting him with a stout leather coat, which she has given, I believe, to no other of his family.

Next for the babies' heads, covered with prickles instead of hair. They are sea urchins, Amphidotus cordatus, which burrow by thousands in the sand. They are of that Spatangoid form which you will often find fossil in the chalk, and which shepherd boys call snakes' heads. We shall soon find another sort, an Echinus, and have time to talk over these most strange (in my eyes) of all living animals.

I must mention Synapta; or, as Montague called it, Chirodota—a much better name, and, I think, very uselessly changed; for Chirodota expresses the peculiarity of the beast, which consists in—start not, reader—twelve hands, like human hands, while Synapta expresses merely its power of clinging to the fingers, which it possesses in common with many other animals. It is, at least, a beast worth talking about; as for finding one, I fear that we have no chance of such good fortune.

But what is it like? Conceive a very fat, short earth-worm; not ringed, though, like the earth-worm, but smooth and glossy, dappled with darker spots, especially on one side, which may be the upper one. Put round its mouth twelve little arms, on each a hand with four ragged fingers, and on the back of the hand a stump of a thumb, and you have Synapta Digitata. These hands it puts down to its mouth, generally in alternate pairs, but how it obtains its food by them is yet a mystery, for its intestines are filled, like an earth-worm's, with the mud in which it lives, and from which it probably extracts (as does the earth-worm) all organic matters.

You will find it stick to your fingers by the whole skin, causing, if your hand be delicate, a tingling sensation; and if you will examine the skin under the microscope, you will find the cause. The whole skin is studded with minute glass anchors, some hanging freely from the surface, but most imbedded in the skin. Each of these anchors is joined at its root into one end of a curious cribriform plate—in plain English one pierced like a sieve, which lies under the skin and reminds one of the similar plates in the skin of the White Cucumaria, which I will show you presently; and both of these we must regard as the first rudiments of an Echinoderm's outside skeleton, such as in the sea-urchins covers the whole body of the animal. The animal, when caught, has a strange habit of self-destruction, contracting its skin at two or three different points, and writhing till it snaps itself into "junks," as the sailors would say, and then dies.

Every ledge of these flat New Red Sandstone rocks, if torn up with the crowbar, discloses in its cracks and crannies nests of strange forms which shun the light of day; beautiful Actiniæ fill the tiny caverns with living flowers; great Pholades bore by hundreds in the softer strata; and wherever a thin layer of muddy sand intervenes between two slabs, long Annelid worms of quaintest forms and colors have their horizontal burrows, among those of that curious and rare radiate animal, the Spoonworm, an eyeless bag about an inch long, half bluish gray, half pink, with a strange scalloped and wrinkled proboscis of saffron color, which serves in some mysterious way, soft as it is, to collect food and clear its dark passage through the rock. See, at the extreme low-water mark, where the broad olive fronds of the Laminariæ, like fan-palms, droop and wave gracefully in the retiring ripples, a great bowlder which will serve our purpose. Its upper side is a whole forest of sea-weeds, large and small; and that forest, if you examined it closely, as full of inhabitants as those of the Amazon or the Gambia. To "beat" that dense cover would be an endless task; but on the under side, where no sea-weeds grow, we shall find full in view enough to occupy us till the tide returns.

Now the crowbar is well under it; heave, and with a will; and so, after five minutes' tugging, propping, slipping, and splashing, the bowlder gradually tips over, and we rush greedily upon the spoil.

The first object which strikes the eye is probably a group of milk-white slugs, from two to six inches long, cuddling snugly together. You try to pull them off, and find that they give you some trouble, such a firm hold have the delicate white sucking arms, which fringe each of their five edges. You see at the head nothing but a yellow dimple; for eating and breathing are suspended till the return of tide; but once settled in a jar of salt water, each will protrude a large chocolate-colored head, tipped with a ring of ten feathery gills, looking very much like a head of "curled kale," but of the loveliest white and primrose; in the centre whereof lies perdu a mouth with sturdy teeth—if, indeed, they, as well as the whole inside of the beast, have not been lately got rid of, and what you see be not a mere bag, without intestine or other organ: but only for the time being. For hear it, worn-out epicures and old Indians who bemoan your livers, this little Holothuria knows a secret which, if he could tell it, you would be glad to buy of him for thousands sterling. To him blue pill and muriatic acid are superfluous and travels to Brunnen a waste of time. Happy Holothuria! who possesses really the secret of everlasting youth, which ancient fable bestowed on the serpent and the eagle. For when his teeth ache, or his digestive organs trouble him, all he has to do is just to cast up forthwith his entire inside, and *faisant maigre* for a month or so, grow a fresh set, and then eat away as merrily as ever. His name, if you wish to consult so triumphant a hygeist, is Cucumaria Pentactes.

Now what are those bright little buds, like salmon-colored Banksia roses half-expanded, sitting closely on the stone? Touch them; the soft part is retracted, and the orange flower of flesh transformed into a pale pink flower of stone. That is the Madrepore (Caryophyllia Smithii); one of our south coast varieties: and see, on the lip of the last one, which we have carefully scooped off with the chisel, two little pink towers of stone, delicately striated; drop them into this small bottle of sea-water, and from the top of each tower issues every half second—what shall we call it?—a hand or a net of finest hairs, clutching at something invisible to our grosser sense.

"Doubtless you are familiar with the stony skeleton of our Madrepore, as it appears in museums. It consists of a number of thin calcareous plates standing up edgewise, and arranged in a radiating manner round a low centre. . . . This is but the skeleton; and though it is a very pretty object, those who are acquainted with it alone can form but a very poor idea of the beauty of the living animal. . . . Let it, after being torn from the rock, recover its equanimity; then you will see a pellucid gelatinous flesh emerging from between the plates, and little exquisitely formed and colored tentacula, with white clubbed tips fringing the sides of the cup-shaped cavity in the centre, across which stretches the oval disk marked with a star of some rich and brilliant color, surrounding the central mouth, a slit with white crenated lips, like the orifice of one of those elegant cowry shells which we put upon out mantel-pieces. The mouth is always more or less prominent, and can be protruded and expanded to an astonishing extent. The space surrounding the lips is commonly fawn color, or rich chestnut-brown, the star or vandyked circle rich red, pale vermilion, and sometimes the most brilliant emerald green, as brilliant as the gorget of a humming bird."*

And what does this exquisitely delicate creature do with its pretty mouth? Alas for fact! It sips no honey-dew, or fruits from paradise. "I put a minute spider, as large as a pin's head, into the water, pushing it down to the coral. The instant it touched the tip of a tentacle it adhered, and was drawn in with the surrounding tentacles between the plates. With a lens I saw the small mouth slowly open and move over to that side, the lips gaping unsymmetrically;

* Gosse, "A Naturalist's Rambles on the Devonshire Coast."

while, with a movement as imperceptible as that of the hour hand of a watch, the tiny prey was carried along between the plates to the corner of the mouth. The mouth, however, moved most, and at length reached the edges of the plates, gradually closed upon the insect, and then returned to its usual place in the centre." (Gosse.) The fact is, that the Madrepore, like those glorious sea-anemones whose living flowers stud every pool, is by profession a scavenger and a feeder on carrion; and being as useful as he is beautiful, really comes under the rule which he seems at first to break, that handsome is who handsome does.

Look now at these tiny saucers of the thinnest ivory, the largest not bigger than a silver threepence, which contain in their centres a milk-white crust of stone, pierced, as you see under the magnifier, into a thousand cells, each with its living architect within. Here are two kinds: in one the tabular cells radiate from the centre, giving it the appearance of a tiny compound flower, daisy or groundsel; in the other they are crossed with waving grooves, giving the whole a peculiar fretted look, even more beautiful than that of the former species. They are Tubulipora patina and Tubulipora hispida; and stay—break off that tiny rough red wart, and look at its cells also under the magnifier: it is Cellepora pumicosa; and now, with the Madrepore, you hold in your hand the principal, at least the commonest, British types of those famed coral insects which in the tropics are the architects of continents and the conquerors of the ocean surge.

There are a few other true cellepore corals round the coast. The largest of all, Cervicornis, may be dredged a few miles outside on the Exmouth bank, with a few more Tubulipores: but all tiny things, the lingering and, as it were, expiring remnants of that great coral-world which, through the abysmal depths of past ages, formed here in Britain our limestone hills, storing up for generations yet unborn the materials of agriculture and architecture. Inexpressibly interesting, even solemn, to those who will think, is the sight of those puny parasites which, as it were, connect the ages and the eons: yet not so solemn and full of meaning as that tiny relic of an older world, the little pear-shaped Turbinolia (cousin of the Madrepores and Sea-anemones), found fossil in the Suffolk crag, and yet still lingering here and there alive in the deep water of Scilly and the west coast of Ireland, possessor of a pedigree which dates, perhaps, from ages before the day in which it was said: "Let us make man in our image, after our likeness."

But we must make haste; for the tide is rising fast, and our stone will be restored to its eleven hours' bath long before we have talked over half the wonders which it holds. Look, though, ere you retreat, at one or two more.

What is that little brown thing whom you have just taken off the rock to which he adhered so stoutly by his sucking-foot? A limpet? Not at all: he is of quite a different family and structure; but on the whole, a limpet-like shell would suit him well enough, so he had one given him: nevertheless, owing to certain anatomical peculiarities, he needed one aperture more than a limpet; so one, if you will examine, has been given him at the top of his shell (Fissurella græca). This is one instance among a thousand of the way in which a scientific knowledge of objects must not obey, but run counter to, the impressions of sense; and of a custom in nature which makes this caution so necessary, namely, the repetition of the same form, slightly modified, in totally different animals, sometimes as if to avoid waste (for why should not the same conception be used in two different cases, if it will suit in both?) and sometimes (more marvelous by far) when an organ, fully developed and useful in one species, appears in a cognate species but feeble, useless, and, as it were, abortive; and gradually, in species still further removed, dies out altogether; placed there it would seem at first sight merely to keep up the family likeness. I am half jesting; that can not be the only reason, perhaps not the reason at all; but the fact is one of the most curious, and notorious also, in comparative anatomy.

Look, again, at those sea-slugs. One, some three inches long, of a bright lemon-yellow, clouded with purple; another of a dingy gray (Doris tuberculata and bilineata); another exquisite little creature of a pearly French white, furred all over the back with what seem arms, but are really gills, of ringed white and gray and black (Eolis papilosa). Put that yellow one into water, and from his head, above the eyes, arise two serrated horns, while from the after part of his back springs a circular Prince-of-Wales's-feather of gills—they are exactly like those which we saw just now in the white Cucumaria. Yes; here is another instance of the same custom of repetition. The Cucumaria is a low radiate animal—the sea-slug a far higher mollusk; and every organ within him is formed on a different type; as, indeed, are those seemingly identical gills, if you come to examine them under the microscope, having to oxygenate fluids of a very different and complicated kind; and, moreover, the Cucumaria's gills were put round his mouth, the Doris's feathers round the other extremity; that gray Eolis's again, are simple clubs, scattered over his whole back, and in each of his nudibranch congeners these same gills take some new and fantastic form; in Melibæa those clubs are covered with warts; in Scyllæa, with tufted bouquets; in the beautiful Antiopa they are transparent bags; and in many other English species they take every conceivable form of leaf, tree, flower, and branch, bedecked with every color of the rainbow, as you may see them depicted in Messrs. Alder and Hancock's unrivaled *Monograph on the Nudibranch Mollusca.*

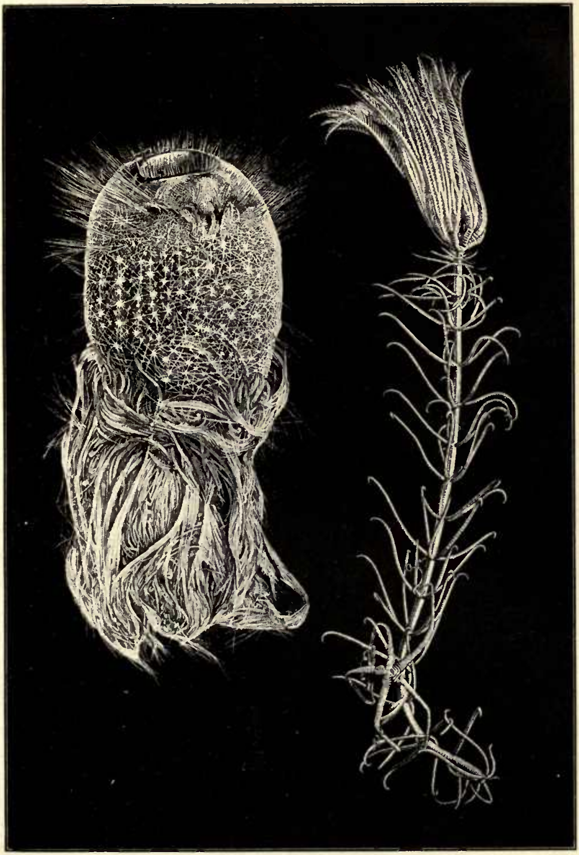
One sight more, and we have done. I had something to say, had time permitted, on the ludicrous element which appears here and there in nature. There are animals, like monkeys and crabs, which seem made to be laughed at; by those at least who possess that most indefinable of faculties, the sense of the ridiculous. But, in the meanwhile, there are animals in which results so strange, fantastic, even seemingly horrible, are produced, that fallen man may be pardoned if he shrinks from them in disgust. At all events, whether we were intruding or not, in turning this stone, we must pay a fine for having done so; for there lies an animal as foul and monstrous to the eye as "hydra, gorgon, or chimæra dire," and yet so wondrously fitted to its work that we must needs endure for our own instruction to handle and to look at it. Its name, if you wish for it, is Nemertes; probably N. Borlasii, a worm of very "low" organization, though well fitted enough for its own work. You see it? That black, shiny, knotted lump among the gravel, small enough to be taken up in a dessert spoon. Look now, as it is raised and its coils drawn out. Three feet—six—nine, at least: with a capability of seemingly endless expansion; a slimy tape of living caoutchouc, some eighth of an inch in diameter, a dark, chocolate black, with paler longitudinal lines. Is it alive? It hangs, helpless and motionless, a mere velvet string across the hand. Ask the neighboring Annelids and the fry of the rock-fishes, or put it into a vase at home, and see. It lies motionless, trailing itself among the gravel; you can not tell where it begins or ends; it may be a dead strip of sea-weed, Himanthalia lorea, perhaps, or Chorda filum, or even a tarred string. So thinks the little fish who plays over and over it, till he touches at last what is too surely a head. In an instant a bell-shaped sucker mouth has fastened to his side. In another instant, from one lip, a concave double proboscis, just like a tapir's (another instance of the repetition of forms), has clasped him like a finger; and now begins the struggle: but in vain. He is being "played" with such a fishing-line as the skill of a Wilson or a Stoddart never could invent; a living line, with elasticity beyond that of the most delicate fly rod, which follows every lunge, shortening and lengthening, slipping and twining round every piece of gravel and stem of sea-weed, with a tiring drag such as no Highland wrist or step could ever bring to bear on salmon or on trout. The victim is tired now; and slowly, and yet dexterously, his blind assailant is feeling and shifting along his side, till he reaches one end of him; and then the black lips expand, and slowly and surely the curved finger begins packing him end foremost into the gullet, where he sinks, inch by inch, till the swelling which marks his place is lost among the coils, and he is probably mascerated to a pulp long before he has reached the opposite extremity of his cave of doom. Once safe down, the black murderer slowly contracts again into a knotted heap, and lies, like a boa with a stag inside him, motionless and blessed.

There; we must come away now, for the tide is over our ankles; but touch, before you go, one of those little red mouths which peep out of the stone. A tiny jet of water shoots up almost into your face. The bivalve (Saxicava rugosa), who has burrowed into the limestone knot (the softest part of the stone to his jaws, though the hardest to your chisel), is scandalized at having the soft mouths of his siphons so rudely touched, and taking your finger for some bothering Annelid, who wants to nibble him, is defending himself; shooting you, as naturalists do humming-birds, with water. Let him rest in peace; it will cost you ten minutes' hard work and much dirt to extract him; but if you are fond of shells, secure one or two of those beautiful pink and straw-colored scallops (Hinnites pusio) who have gradually incorporated the layers of their lower valve with the roughness of the stone, destroying thereby the beautiful form which belongs to their race, but not their delicate color. There are a few more bivalves, too, adhering to the stone, and those rare ones, and two or three delicate Mangeliæ and Nassæ are trailing their graceful spires up and down in search of food. That little bright red and yellow pea, too, touch it—the brilliant colored cloak is withdrawn, and, instead, you have a beautiful ribbed pink cowry (Cypræa Europæa), the only European representative of that grand tropical family. Cast one wondering glance, too, at the forest of zoophytes and corals, Lepraliæ and Flustræ, and those quaint blue stars, set in brown jelly, which are no zoophytes, but respectable mollusks, each with his well-formed mouth and intestines (Botrylli), but combined in a peculiar form of communism, of which all one can say is that one hopes they like it.

From the bare rocks above high-water mark, down to abysses deeper than ever plummet sounded, is life, everywhere life; fauna after fauna, and flora after flora, arranged in zones, according to the amount of light and warmth which each species requires, and to the amount of pressure which they are able to endure. The crevices of the highest rocks, only sprinkled with salt-spray in spring-tides and high gales, have their peculiar little univalves, their crisp lichen-like sea-weed, in myriads; lower down, the region of the Fuci (bladder-weeds) has its own tribes of periwinkles and limpets; below again, about the neap-tide mark, the region of the Corallines and Algæ furnishes food for yet other species who graze on its watery meadows; and beneath all, only uncovered at low spring-tide, the zone of the Laminariæ (the great tangles and ore-weeds) is most full of all of every imaginable form of life.

CRABS, PRAWNS, AND LOBSTERS.—Philip Henry Gosse

IF you look at the head of a crab, a lobster, or a prawn, you will see that it is furnished with jointed antennæ, like that of insects; but whereas in insects there is never more than a single pair, in the creatures of which I am speaking there are two pairs. In the prawn you may suppose, at first sight, that there are four pairs; but that is because the internal antennæ terminate each in three many-jointed bristles, in structure and appearance exactly like the bristles of the outer pair, two of the three being nearly as long as the outer, while the third is short. In the lobster, the internal are two-bristled, both bristles rather short, while the external are very long. In the flat-crabs each pair is simple, the inner minute, the outer long. In the great eatable crab each pair is very small, and they are dissimilar.



Two Strange *Zoophytes*

1, *Holtenia Carpenteri*, a species of glass sponge; 2, *Pentacrinus Asteria*, the only survivor of the Crinoid family

Now taking the last-named animal as the representative of his class, let us examine one of his inner antennæ first. It consists of a jointed stem and a terminating bristle; the latter furnished with small hairs common to the general surface of the body, and with long, delicate, membraneous filaments (*setæ*), often improperly called *cilia,* which are larger and much more delicate in structure than the ordinary hairs.

The basal joint is greatly enlarged: if it be carefully removed from its connection with the head, and broken open, it will be found to inclose in its cavity a still smaller chamber, with calcareous walls of a much more delicate character than the outer walls. This internal shell is considered by Mr. Spence Bate to be a *cochlea*, from its analogy, both in structure and supposed use, to the organ so named in the internal ear of man and other vertebrate animals. It is situated, as has been said, in the cavity of the basal joint of the internal antennæ, and is attached to the interior surface of its wall furthest from the median line of the crab. It has a tendency to a spiral form, but does not pass beyond the limits of a single convolution.

If this interior cell does indeed represent the *cochlea* of more highly constructed ears—to which it bears some resemblance, both in form and structure—then it seems to identify, beyond dispute, these inner or upper antennæ as the organs of hearing.

Now with this conclusion agrees well the manner in which the living animal makes use of the organs in question. The crab always carries them erect and elevated; and is incessantly striking the water with them, with a very peculiar jerking action, now and then vibrating, and, as it has been called, "twiddling" them. These antennæ, therefore, appear to be always on the watch: let the animal be at rest, let it be feeding, no matter, the superior antennæ are ever elevated and on constant guard.

The lengthened and delicate setæ with which they are furnished are, moreover, peculiarly adapted to receive and convey the most minute vibratory sensations from the medium in which they are suspended; and, on the whole, it seems to be satisfactorily settled by Mr. Spence Bate (to whose excellent memoir I am indebted for these explanatory details) that the inner antennæ are real *ears*.

Having thus taken our crab by the ears, we will endeavor next to tweak his nose. But stay, we must find it first. We turn our horny gentleman up, and in his flat ancient face we certainly discern little sign of a nasal organ. Our friend Mr. Bate must assist us again. He will tell us to look at the outer or lower antennæ. We will look accordingly, magnifier in hand, while he makes it clear to us that these are a pair of noses.

Each of these organs is formed of a stem consisting in general of five joints, and a filament of many minute joints. In the prawn and the lobster all the five joints of the stem are distinct; but in the crab the whole are, as it were, soldered together into a compact mass, with difficulty distinguishable into their constituent articulations; while in some species their position can be indicated only by the presence of the olfactory operculum.

This important little organ varies in its construction in the different families of Crustacea. In the crab it is a small movable appendage, situated at the point of junction between the second and third joints; it is attached to a long, calcareous, lever-like tendon, at the extreme limit of which is placed a set of muscles, by which it is opened and closed; to assist in which operation, at the angle of the operculum most distant from the central line of the animal are fixed two small hinges. When the operculum is raised, the internal surface is found to be perforated by a circular opening protected by a thin membrane.

In the prawn, shrimp, and lobster, there is no operculum, but only the orifice covered by a membrane, which is placed at the extremity of a small protuberance, and it is not capable of being withdrawn into the cavity of the antennæ, as in the crab.

In the latter animal, the little door, when it is raised, exposes the orifice in a direction pointing to the mouth; and where there is no door, still the direction of the opening is the same, inward and forward, answering to the position of the nostrils in the higher animals. In each case it is so situated that it is impossible for any food to be conveyed into the mouth without passing under this organ; and there most conveniently the animal is enabled to judge of the suitability of any substance for food, by raising the little door, and applying to the matter to be tested the sensitive membrane of the internal orifice.

Thus it is concluded that this lower or outer pair of antennæ are the proper organs of smell, as the upper and inner are of hearing.

The eyes, though constructed on the same general principles as those of insects, yet present some particulars worthy of your notice. In the crabs and lobsters they consist of numerous facets, behind each of which is a conical or prismatic lens, the round extremity of which is fitted into a transparent conical pit, corresponding to a vitreous body, while the conical extremity of these lenses is received into a kind of cup, formed by the filaments of the optic nerve. Each of these filaments, together with its cup, is surrounded by pigment matter in a sheath-like manner. To see this structure would require anatomical skill; but you may here examine with a low power portions of the cornea, or glassy exterior, of the eye of a crab and of a lobster. In the former, you see that the facets into which the cornea is divided are hexagonal, like those of most insects, but in the latter they are square.

But Crustacea have a far greater faculty of circumspection than insects have; for besides the extensive convexity and numerous facets of their eyes, these organs are placed at the extremity of shelly foot-stalks, which are themselves movable on hinges, capable of being projected at pleasure, of being moved in different directions, and of being packed snugly away, when not in active use, in certain grooves hollowed out expressly for them in the front margin of the shell.

REPTILES.—Peter Mark Roget

THE order of Batrachia, or Amphibious Reptiles, constitutes the first step in the transition from aquatic to terrestrial vertebrata. It is more particularly the function of respiration that requires to be modified, in consequence of the change of element in which the animal is to reside; and as if it had been necessary, conformably to the laws of animal creation, that this change should not be abruptly made, we find that Batrachian reptiles, with which this series commences, are constructed, at first, on the model of fishes; breathing the atmospheric air contained in the water by means of gills, and moving through the fluid by the same instruments of progression as fishes, which, indeed, they exactly resemble in every part of their mechanical conformation. The tadpole, which is the young of the frog, is, at first, not distinguishable in any circumstance of its internal skeleton, or in the disposition of its vital organs, from the class of fishes. The head, indeed, is enlarged, but the body immediately tapers to form a lengthened tail, by the prolongation of the spinal column, which presents a numerous series of coccygeal vertebræ, furnished with a vertical expansion of membrane to serve as a caudal fin, and with appropriate muscles for executing all the motions required in swimming.

Yet, with all this apparent conformity to the structure of a strictly aquatic animal, the tadpole contains within its organization the germs of a higher development. Preparations are silently making for a change of habitation, for the animal's emerging from the waters, for the reception of atmospheric air into new cavities, for the acquisition of limbs suited to new modes of progression; in a word, for a terrestrial life, and for all the attributes and powers which belong to quadrupeds. The succession of forms, which these metamorphoses present, are in themselves exceedingly curious, and bear a remarkable analogy with the progress of the transformations of those insects, which in the first stages of their existence are aquatic. To this philosophic inquirer into the marvelous plans of creation, the series of changes which mark these singular transitions can not fail to be deeply interesting; and occurring, as we here find them, among a tribe of animals allied to the more perfect forms of organization, they afford us a better opportunity of exploring the secrets of their development by tracing them from the earlier stages of this complicated process, so full of mystery and of wonder.

The egg of the frog is a round mass of transparent nutritive jelly, in the centre of which appears a small black globule. By degrees this shapeless globule exhibits the appearance of a head and tail, and in this form it emerges from its prison, and moves briskly in the water. From the sides of the neck there grow out feathery tufts, which float loosely, and without protection, in the surrounding fluid. These, however, are mere temporary organs, for they serve the purposes of respiration only until the proper gills are formed, and they then shrink and become obliterated. The true gills, or *branchiæ,* are contained within the body, and are four in number on each side, constructed on a plan very similar to those of fishes. Retaining this aquatic constitution, the tadpole rapidly increases in size and in activity for several weeks. In the meantime the legs, of which no trace was at first apparent, have commenced their growth. The hindlegs are the first to make their appearance, showing their embryo forms within the transparent coverings of the hinder part of the trunk, just at the origin of the tail. These are soon succeeded by the forelegs, which exactly follow the hindlegs in all the stages of their development, until they have acquired their due proportion to the size of the trunk. The animal at this period wears a very ambiguous appearance, partaking of the forms both of the frog and of the lizard, and swimming both by the inflexions of the tail and the irregular impulses given by the feet. This interval is also employed by this amphibious being in acquiring the faculty of respiring atmospheric air. We observe it rising every now and then to the surface, and cultivating its acquaintance with that element, into which it is soon to be raised; occasionally taking in a mouthful of air, which is received into its newly developed lungs, and afterward discharging it in the form of a small bubble. When the necessary internal changes are at length completed, preparations are made for getting rid of the tail, which is now a useless member, and which, ceasing to be nourished, diminishes by degrees, leaving only a short stump, which is soon removed. The gills are by this time shrunk, and rapidly disappear, their function being superseded by the lungs, which have been called into play; and the animal now emerges from the water and begins a new mode of existence, having become a perfect frog. It still, however, retains its aquatic habits, and swims with great ease in the water by means of its hindfeet, which are very long and muscular, and of which the toes are furnished with a broad web, derived from a thin extension of the integuments.

No less curious are the changes which take place in all the other organs for the purpose of effecting the transformations rendered necessary by this entire alteration in all the external circumstances of that animal—this total reversal of its wants, of its habits, of its functions, and of its very constitution.

There are five toes in the foot, with sometimes the rudiment of a sixth: the anterior extremity has only four toes, which are without claws.

The necessity of employing the same instruments for progression in the water and on land is probably the cause which prevents their having the form best adapted for either function. The hindfeet of the frog, being well constructed for striking the water backward in swimming, are, in consequence, less capable of exerting a force sufficient to raise and support the weight of the body in walking: and this animal accordingly is exceedingly awkward in its attempt to walk. On a short level plane it can proceed only by leaps; an action which the length and great muscularity of the hindlegs particularly fit them for performing. The toad, on the other hand, whose hindlegs are short and feeble, walks better, but does not jump or swim so well as the frog.* The Hyla, or tree-frog, has the extremities of each of its toes expanded into a fleshy tubercle, approaching in the form of its concave surface to that of a sucker, and by the aid of which it fastens itself readily to the branches of trees, which it chiefly inhabits, and along which it runs with great agility.

The salamander is an animal of the same class as the frog, undergoing the same metamorphoses from the tadpole state. It differs much, however, in respect to the development of particular parts of the skeleton. The anterior extremities of the salamander make their appearance earlier than the hindlegs, and the tail remains as a permanent part of the structure. The land salamanders have a rounded tail, but the aquatic species, or Tritons, have it compressed vertically; thus retaining the fish-like form of the tadpole, and the same radiated disposition of the muscles.

In the class of serpents we see exemplified the greatest possible state of simplicity to which a verte-

* It is singular that the frog, though so low in the scale of vertebrated animals, should bear a striking resemblance to the human conformation in its organs of progressive motion. This arises from the exertions which it makes in swimming being similar to those of man in walking, in as far as they both result from the strong action of the extensors of the feet. Hence, we find a distinct calf in the legs of both, produced by the swelling of similar muscles. The muscles of the thigh present, also, many analogies with those of man; particularly in the presence of the long muscle called the *sartorius,* the use of which is to turn the foot outward, both in stepping and in swimming.

brated skeleton can be reduced; for it consists merely of a lengthened spinal column, with a head but little developed, and a series of ribs; but apparently destitute of limbs, and of the bones which usually connect those limbs with the trunk. In the conformation of the skull and bones of the face, they present strong analogies with Batrachian reptiles, and also with fishes, one tribe of which, namely, the apodous or anguilliform fishes, they greatly resemble by the length and flexibility of the spine. These peculiarities of conformation may be in a great measure traced to the mode of life for which they are destined. The food assigned to them is living prey, which they must attack and vanquish before they can convert it into nourishment. The usual mode in which the boa seizes and destroys its victims is by coiling the hinder part of its body round the trunk or branch of a tree, keeping the head and anterior half of the body disengaged; and then, by a sudden spring, fasten upon the defenceless object of its attack, and twining round its body so as to compress its chest and put a stop to its respiration. Venomous serpents, on the other hand, coil themselves into the smallest possible space, and suddenly darting upon the unsuspecting or fascinated straggler, inflict the quickly fatal wound.*

It is evident, from these considerations, that, in the absence of all external instruments of prehension

* Their prey is swallowed entire; and therefore, as we shall afterward find, the bones of the jaws and face are formed to admit of great expansion, and of great freedom of motion upon one another.

and of progressive motion, it is necessary that the spine should be rendered extremely flexible, so as to adapt itself to a great variety of movements. This extraordinary flexibility is given, first, by the subdivision of the spinal column into a great number of small pieces; secondly, by the great freedom of their articulations; and thirdly, by the peculiar mobility and connections of the ribs.

Numerous as are the vertebræ of the eel, the spine of which consists of above a hundred, that of serpents is in general formed of a still greater number. In the rattle-snake (Crotalus horridus) there are about two hundred; and above three hundred have been counted in the spine of the Coluber natrix. These vertebræ are all united by ball and socket joints, as in the adult batrachia; the posterior rounded eminence of each vertebra being received into the anterior surface of the next.

While provision has thus been made for extent of motion, extraordinary care has at the same time been bestowed upon the security of the joints. Thus, we find them effectually protected from dislocation by the locking in, above and below, of the articular processes, and by the close investment of the capsular ligaments. The direction of the surfaces of these processes, and the shape and length of the spinous prosesses, are such as to allow of free lateral flexion, but to limit the vertical and longitudinal motions: and whatever degree of freedom of motion may exist between the adjoining vertebræ, that motion being multiplied along the column, the flexibility of the whole becomes very great, and admits of its assuming every degree and variety of curvature.

The mode in which the boa exerts a powerful pressure on the bodies of the animals it has seized, and which it has encircled within its folds, required the ribs to be movable laterally, as well as backward, in order to elude the force thus exerted. The broad convex surfaces on which they play give them, in this respect, an advantage which the ordinary mode of articulation would not have afforded. The spinous processes in this tribe of serpents are short and widely separated, so as to allow of flexion in every direction. In the rattlesnake, on the other hand, their length and oblique position are such as to limit the upward bending of the spinal column, although, in other respects, its motion is not restricted. The vertebræ at the end of the tail are furnished with broad transverse processes for the attachment of the first joints of the rattle.

But of whatever variety of flexions we may suppose the lengthened body of a serpent to be capable, it will, at first view, be difficult to conceive how these simple actions can be rendered subservient to the purposes of progression on land: and yet experience teaches us that few animals advance with more celerity on the surface of the ground, or dart upon their prey with greater promptitude and precision. They raise themselves without difficulty to the tops of the highest trees, and escape to their hiding-places with a quickness which eludes observation and baffles the efforts of their pursuers.

The solution of this enigma is to be sought for partly in the structure of the skin, which, in almost every species, is covered with numerous scales: and partly in the peculiar conformation of the ribs. The edges of the scales form rough projections, which are directed backward, so as to catch the surfaces of the bodies to which they are applied, and to prevent any retrograde motion. In some species, the integument is formed into annular plates, reminding us of the structures so prevalent among worms and myriapode animals. Each scale is connected with a particular set of muscular fibres, capable of raising or depressing it, so that, in this way, it is converted into a kind of toe; and thus the body rests upon the ground by numerous fixed points of support.

This support is further strengthened by the connection of the ribs with the abdominal *scuta*, or the scales on the under side of the body. The mode in which the ribs become auxiliary instruments of progressive motion was first noticed by Sir Joseph Banks. While he was watching the movements of a Coluber of unusual size which was exhibited in London, and was moving briskly along the carpet, he thought he saw the ribs come forward in succession, like the feet of a caterpillar. Sir Everard Home, to whom Sir Joseph Banks pointed out this circumstance, verified the fact by applying his hand below the serpent, and he then distinctly felt the ends of the ribs moving upon the palm, as the animal passed over it. The mode in which the ribs are articulated with the spine is peculiar, and has evidently been employed with reference to this particular function of the ribs, which here stand in place of the anterior and posterior extremities, possessed by most vertebrated animals, and characterizing the type of their osseous fabric. In the ordinary structure, the head of each rib has a convex surface, that plays either on the body of a single vertebra with which it is connected, or upon the two bodies of adjacent vertebræ: but in serpents the extremity of the head of the rib has two slightly concave articular surfaces, which play on a convex protuberance of the vertebra. This structure is attended with the advantage of preventing the ribs from interfering with the motions of the vertebræ upon one another. At their lower ends the ribs of one side have no connection with those of the other, nor are they joined to any bone analogous to a sternum: for, except in the Ophiosaurus and the blind-worm (Anguis fragilis), there is no vestige either of a sternum or scapula, in any animal of this class. Each rib terminates in a slender cartilage, tapering to a point, which rests, for its whole length, upon the upper surface of one of the scuta, or broad scales on the lower side of the body. These scuta, which are thus connected with the ends of the ribs, and which are moved by means of short muscles, may be compared to hoofs, while the ribs themselves may be considered as performing the office of legs. The ribs move in pairs; and the scutum under each pair, being carried along with it in all its motions, and laying hold of the ground by its projecting edge, becomes a fixed point for the advance of the body. This motion, Sir E. Home observes, is beautifully seen when a snake is climbing over an angle to get upon a flat surface. When the animal is moving on a plane, it alters its shape from a circular or oval form, to one that approaches to a triangle, of which the surface applied to the ground forms the base. Five sets of muscles are provided for the purpose of giving to the ribs the motions backward and forward, by which, as levers, they effect this species of progression. These muscles are disposed in regular layers; some passing over one or two ribs to be attached to the succeeding rib. In all snakes the ribs are continued backward much beyond the region occupied by the lungs; and although the anterior set are subservient to respiration, as well as to progressive motion, it is evident that all those posterior to the lungs must be employed solely for the latter of these purposes.

It is easy to understand how the serpent can slowly advance, by this creeping, or vermicular motion, consisting in reality of a succession of very short steps. But its progress is accelerated by the curvatures into which it throws its body; the fore part being fixed, and the hind part brought near to it; then, by a reverse process, the hind part is fixed, and the head projected forward. By an alternation of these movements, assisted by the actions of the ribs, the serpent is enabled to glide onward with considerable rapidity, and without attracting observation. But where greater expedition is necessary, they employ a more hurried kind of pace, although one which exposes them more to immediate view. The body, instead of being bent from side to side, is raised in one great arch, of which the two extremities alone touch the ground; and these being alternately employed as points of support, are made successively to approach and to separate from each other, the body being propelled by bringing it from a curved to a straight line.

There is yet a third kind of motion, which serpents occasionally resort to, when springing upon their prey, or when desirous of making a sudden escape from danger. They coil themselves into a spiral, by contracting all the muscles on one side of the body, and then, suddenly throwing into violent action all the muscles on the opposite side, the whole body is propelled, as if by the release and unwinding of a powerful spring, with an impulse which raises it to some height from the ground, and projects it to a considerable distance.

Thus these animals, to which nature has denied all external members, are yet capable, by the substitution of a different kind of mechanism, still constructed from the elements belonging to the primitive type of vertebrated animals, of silently gliding along the surface of the earth, of creeping up trees, of striding rapidly across the plain, and of executing leaps with a vigor and agility which astonish the beholder, and which, in ages of ignorance and superstition, were easily ascribed to supernatural agency.

The conformation of those parts of the frame which are subservient to progressive motion becomes more perfect in the class of Saurian reptiles, which includes all the lizard tribes. Several links of connection with the preceding class may still be noticed, marking the progress of development, as we follow the ascending series of animals. Rudiments of the bones of the extremities, and, also, of the sternum, make their appearance very visibly in the Ophiosaurus, and in the blind-worm (Anguis fragilis). The Siren lacertina has two diminutive forefeet, placed close to the head. The Lacerta lumbricoides of Linnæus, or the Bipes canaliculatus of Lacepede, which is found in Mexico, and of which a specimen is preserved in the collection at Paris, has a pair of very short feet, also placed near the head, and divided into four toes, with the rudiment of a fifth. The Lacerta bipes (Linn.), or Sheltopusic of Pallas, has, on the other hand, a pair of hindfeet only, but extremely small, together with rudiments of a scapula and clavicle concealed under the skin. Next in order must be placed the Chalcides, or snake-lizard, and the Lacerta seps, animals frequently met with in the south of France, and which have four minute feet, totally inefficient for the support of the body, and only remotely useful in contributing to its progressive undulations.

Ascending from these, we may form a series of reptiles, in which the development of the limbs becomes more and more extended, till we arrive at crocodiles, in which they attain a considerable degree of perfection. As a consequence of this greater development of the skeleton, we find the trunk divisible into separate regions. We now, for the first time, meet with a distinct neck, separating the head from the thorax, which is itself distinguishable from the abdomen; and a distinct sacrum is interposed between the lumbar and the caudal vertebræ.

The number of ribs differs in different species of

Sauria: they are always articulated to the extremities of the transverse processes of the vertebræ, of which they appear to be continuations. Processes of this description also occur in the neck, attached to the transverse processes of the cervical vertebræ; and these have been regarded as *cervical ribs.* Their presence are impediments to the flexions of the neck; whence arises the difficulty which the crocodile appears to have in bending the neck, while turning round upon the animal he is pursuing. In the thorax, the ribs are connected with a broad sternum; but there are other ribs, both before and behind, which have no such termination, and therefore bear the name of *false ribs.*

The toes are usually provided with membranes spread between them, to assist in swimming. The form of the tail, which is generally compressed vertically, like that of fishes, though perhaps not to an equal degree, is another indication of their being formed for an aquatic life: for where the tail has this shape, we always find that the chief muscular power is bestowed upon it as an instrument of aquatic progression, producing, by its lateral flexions, a horizontal movement of the body. Crocodiles and alligators, for instance, which have this conformation, are comparatively weak when on land, and as soon as they have seized their prey their efforts are always directed to drag it with them into the water; knowing that when in their own element they can readily master its struggles, and dispose of it as they please.

In the Gecko tribe we find a particular mechanism provided for effecting the adhesion of the feet to the objects to which they are applied. It is somewhat analogous to that employed in the case of the housefly, already mentioned. Each foot has five toes; all, except the thumb, terminated by a sharp curved claw. On the under surface of each toe there are as many as sixteen transverse slits, leading to the same number of cavities, or sacs; these open forward, and their external edge is serrated, appearing like the teeth of a small-toothed comb. All these parts, together with the cavities, are covered or lined with cuticle. Below them are large muscles which draw down the claw; and from the tendons of these muscles arise two sets of smaller muscles, situated so as to be put upon the stretch, when the former are in action. By the contractions of these muscles the orifices of the cavities, or sacs to which they belong, are opened, and the serrated edges applied accurately to the surfaces with which the feet are in contact. Sir Everard Home, in his account of this structure, compares it to the sucking disk of the Remora. By its means the animal is enabled to walk securely upon the smoothest surfaces, even in opposition to the tendency of gravity. It can run very quickly along the walls or ceiling of a building, in situations where it can not be supported by the feet, but must depend altogether upon the suspension derived from a succession of rapid and momentary adhesions.

Although the Sauria are better formed for progressive motion than any of the other orders of reptiles, yet the greater shortness and oblique position of their limbs, compared with those of mammiferous quadrupeds, obliges them in general to rest the weight of the trunk of the body on the ground, when they are not actually moving. None of these reptiles has any other kind of pace than that of walking or jumping; being incapable of performing either a trot or a gallop, in consequence of the obliquity of the plane in which their limbs move. The chameleon walks with great slowness and apparent difficulty; and we have seen that, in consequence of the structure of the bones of its neck, the crocodile, though capable of swift motion in a straight line, is unable to turn itself round quickly. The general type of these reptiles, having reference to an amphibious life, has not attained that exclusive adaptation to a terrestrial existence which we find in the higher orders of the Mammalia.

The order of Chelonian Reptiles, which comprises all the tribes of tortoises and turtles, appears to constitute an exception to the general laws of conformation which prevail among vertebrated animals: for instead of presenting a skeleton wholly internal, the trunk of the body is found to be inclosed on every side in a bony case, which leaves openings only for the head, the tail, and the fore and hind extremities. That portion of this osseous expansion which covers the back is termed the Carapace; and the flat plate which defends the lower part of the body is termed the Plastron. It is a form of structure that reminds us of the defence provided for animals very low in the scale of organization, such as the echinus, the crustacea, and the bivalve mollusca. Yet the substance which forms these strong bucklers, both above and below, is a real osseous structure, developed in the same manner as other bones, subject to all the changes and having all the properties of these structures. The great purpose which Nature seems to have had in view in the formation of the Chelonia is security; and for the attainment of this object she has constructed a vaulted and impenetrable roof, capable of resisting enormous pressures from without, and proof against any ordinary measures of assault. It is to the animal a strong castle, into which he can retire on the least alarm, and defy the efforts of his enemies to dislodge or annoy him.

These considerations supply us with a key to many of those apparent anomalies which can not fail to strike us in viewing the dispositions of the parts of the skeleton and the remarkable inversion they appear to have undergone, when compared with the usual arrangement. We find, however, on a more attentive examination, that all the bones composing the skeleton in other vertebrated animals exist also in the tortoise; and that the bony case which envelops all the other parts is really formed by an extension of the spinous processes of the vertebræ and ribs on the one side and of the usual pieces which compose the sternum on the other. The upper and lower plates thus formed are united at their edges by expansions of the sternocostal appendices, which become ossified. Thus, no new element has been created; but advantage has been taken of those already existing in the general type of the vertebrata, to modify their forms by giving them different degrees of relative development, and converting them, by these transformations, into a mechanism of a very different kind, and subservient to other objects than those to which they are usually applied. It is scarcely possible to have stronger proofs, if such were wanting, of the unity of plan which has regulated the formation of all animal structures than those afforded by the skeleton of the tortoise.

The first step taken to secure the relative immobility of the trunk is to unite in one rigid, bony column all its vertebræ, and to allow of motion only in those of the neck and of the tail. The former, accordingly, are all anchylosed together, leaving, indeed, traces of their original forms as separate vertebræ, but exhibiting no sutures at the place of junction. The canal for the spinal marrow is preserved, as usual, above the bodies of these coalesced vertebræ, and is formed by their united leaves; the arches being completed by the spinous processes. But these processes do not terminate in a crest as usual; they are further expanded in a lateral direction, forming flat pieces along the back, which are united to one another by sutures, and which are also joined to the expanded ribs, so as to form the continuous plane surface of the carapace. The transverse processes of the vertebræ are well marked, but, though firmly united to the ribs, do not give rise to them; for the ribs, which are flattened and expanded, so as to touch one another along their whole length, are inserted below, between the bodies of every two adjoining vertebræ; while above they are united by suture with the plates of the spinous processes. This change in the situation of the ribs is the consequence of the change in their office. When designed to be very movable, we find them attached either to the extremities of the transverse processes or to the articular surfaces of a single vertebra; but where solidity and security are aimed at, they are always inserted between the bodies of two vertebræ. It is remarkable, indeed, that a great number of the peculiarities which distinguish the conformation of the chelonia from that of other reptiles indicate an approach to the structure of birds; as if Nature had intended this mall group of animals to be an intermediate link of gradation to that new and important type of animals destined for a very different mode of existence.

It is to be noticed, also, that as the plates, which form this investing case, are bony structures, they could not with any safety have been exposed to the action of the atmosphere. Hence we find them covered throughout with a thin, horny plate, originally a production of the integument. This substance is commonly known by the name of tortoise shell.

The immobility of the trunk is compensated, as far as regards the safety of the head, by the great flexibility of the neck; which is composed of seven vertebræ, unencumbered by processes, and capable of taking a double curvature like the letter S, when the head is to be retracted within the carapace. These vertebræ are joined by the ball and socket articulation common to all the *existing* species of reptiles.*

* The expression of this fact is thus qualified, because it does not apply to many fossil or extinct species, such as the Ichthyosaurus.

The articulation of the head with the neck is effected in the same manner; but it is interesting to remark that the occipital condyle, which is situated at the lower margin of the great aperture, though presenting a single convex surface, yet has that surface evidently divided into three parts; the two upper portions being lateral and the lower portion in the middle.

The singular conformation of the bones of the head, in the turtle, affords fresh evidence in support of the theory that these bones were originally vertebræ. The brain of the tortoise is exceedingly small; and yet the skull, when viewed from above, presents an appearance of great breadth, as if it inclosed a cavity of large dimensions. This great breadth of the head in the turtle gives the animal an aspect of superior intelligence, to which character, from the really diminutive size of its brain, it is in no respect entitled. As the turtle is unable to withdraw its head within the carapace, such extraordinary protection appears to have been necessary: for it is not met with in the tortoise, which has a carapace sufficiently capacious to give shelter to the head whenever occasion may require.

All the feet are joined obliquely to the limbs which support them, giving the animal an apparent awkwardness of gait, as if it were obliged to walk upon club feet. The impulse which they give being lateral and oblique, renders them more efficacious for progression in the water than on land: this circumstance, in conjunction with the constitutional torpor of the animal, sufficiently accounts for the excessive and, indeed, proverbial tardiness of its movements.

Security appears still to be the object aimed at in the mechanism of all other parts of the skeleton. After the head has been drawn in by the double or serpentine flexion of the neck, the knees are brought together and the whole limb withdrawn within the shell, the forelegs folding completely over the head, so as to cover and protect it most effectually.

Considerable differences may be noticed in the structure of the several species of Chelonia, according to the diversity of their habits. Tortoises which live on land require more complete protection by means of their shell than turtles, or Emydes, which dwell only in the water: hence the convexity of their carapace, the solidity of its ossification, its immovable connection with the plastron, and the complete shelter it affords to the head and limbs. Turtles, on the other hand, receiving support from the element in which they reside, require less provision to be made for these objects. Previously to the retraction of the head and limbs within the shell, the air is expelled from the large cavities of the lungs by the vigorous actions of the abdominal muscles, which exist in these animals as well as in all the vertebrata, although here they are covered by the bones, and compress the lungs by pushing the abdominal viscera against them. This sudden expulsion of air is the cause of the long-continued hissing sound which the tortoise emits while preparing to retreat into its stronghold.

The ribs, though they first assume the form of broad plates immovably united to the spine, when they have proceeded a certain distance separate from each other and resume their usual form; the intervening spaces between two adjacent ribs being here filled up by membrane. The plastron is united with the carapace by membrane likewise; and the sternum, instead of forming one broad plate of bone, has the intervals between its imperfectly developed elements also membraneous. All this renders the whole shell less compact, more flexible, and more feeble: but the movements of the animal are quicker and more energetic.

These characteristic differences between the aquatic Chelonia and those that live on land are still more strongly marked in the genus Trionyx, or soft tortoise, which is destitute of scales, and in which many of the pieces that are bony in the tortoise are replaced by simple cartilage or membrane.

The enormous weight of the shell of the turtle would be a serious impediment to the motion of this animal in the water, were there not some provision made for diminishing the specific gravity in the body. This purpose is answered by the great capacity of the lungs, which, when inflated with air, nearly fill the thorax, and give great buoyancy to the whole mass. Thus, wherever there exists a supposed inconvenience, dependent on the fulfilment of one condition, we are certain to meet with a compensation in the structure of some other part and in the mode of executing some other function. An express provision for giving buoyancy has been made in the construction of the shell of a species of tortoise inhabiting the coasts of the Scychelle Islands. The under surface of the shell, instead of being gently concave, as in land tortoises, has a deep circular concavity in the centre, above four inches in depth, which, when the animal goes into the water, retains a large volume of air, buoying up the whole mass while it remains in that element. The greater size of turtles, when compared with tortoises, is a further instance of the superior facility with which organic growth proceeds in aquatic than in land animals formed on the same model of construction.

THE CLASSIFICATION AND ORIGIN OF INSECTS.—Lord Avebury

ABOUT sixty years ago the civil and ecclesiastical authorities of St. Fernando in Chili arrested a certain M. Renous on a charge of witchcraft because he kept some caterpillars which turned into butterflies. This was no doubt an extreme case of ignorance; it is now almost universally known that the great majority of insects quit the egg in a state very different from that which they ultimately assume; and the general statement in works on entomology has been that the life of an insect may be divided into four periods.

Thus, according to Kirby and Spence, "the states through which the insects pass are four: the *egg*, the *larva*, the *pupa*, and the *imago*." Burmeister, also, says that, excluding certain very rare anomalies, "we may observe four distinct periods of existence in every insect—namely, those of the egg, the larva, the pupa, and the imago, or perfect insect." In fact, however, the various groups of insects differ widely from one another in the metamorphoses they pass through: in some, as in the grasshoppers and crickets, the changes consist principally in a gradual increase of size, and in the acquisition of wings; while others, as, for instance, the common fly, acquire their full bulk in a form very different from that which they ultimately assume, and pass through a period of inaction in which not only is the whole form of the body altered, not only are legs and wings acquired, but even the internal organs themselves are almost entirely disintegrated and re-formed.

The following list gives the orders or principal groups into which the Class Insecta may be divided. I will not, indeed, here enter upon my own views, but will adopt the system given by Mr. Westwood in his excellent *Introduction to the Modern Classification of Insects*. He divides insects into thirteen groups, and with reference to eight of them it may be said that there is little difference of opinion among entomologists. These orders are by far the most numerous, and I have placed them in capital letters. As regards the other five there is still much difference of opinion. It must also be observed that Prof. Westwood omits the parasitic Anoplura, as well as the Thysanura and Collembola.

ORDERS OF INSECTS ACCORDING TO WESTWOOD

1. HYMENOPTERA . Bees, Wasps, Ants, etc.
2. Strepsiptera . . Stylops, Zenos, etc.
3. COLEOPTERA . . Beetles.
4. Euplexoptera . . Earwigs.

5. ORTHOPTERA . .	Grasshoppers, Crickets, Cockroaches, etc.
6. Thysanoptera .	Thrips.
7. NEUROPTERA . .	Ephemeras, etc.
8. Trichoptera . .	Phryganea.
9. DIPTERA . . .	Flies and Gnats.
10. Aphaniptera	Fleas.
11. HETEROPTERA .	Bugs.
12. HOMOPTERA . .	Aphis, Coccus, etc.
13. LEPIDOPTERA . .	Butterflies and Moths.

Of these thirteen orders, the eight which I have placed in capital letters—namely, the first, third, fifth, seventh, ninth, eleventh, twelfth, and thirteenth—are much the most important in the number and variety of their species; the other five form comparatively small groups. The Strepsiptera are minute insects, parasitic on Hymenoptera: Rossi, by whom they were discovered, regarded them as Hymenopterous; Lamarck placed them among the Diptera; by others they have been considered to be most closely allied to the Coleoptera, but they are now generally treated as an independent order.

The Euplexoptera or Earwigs are only too familiar to most of us. Linnæus classed them among the Coleoptera, from which, however, they differ in their transformations. Fabricius, Olivier, and Latreille regarded them as Orthoptera; but Dr. Leach, on account of the structure of their wings, considered them as forming the type of a distinct order, in which view he has been followed by Westwood, Kirby, and many other entomologists.

The Thysanoptera, consisting of the Linnæan genus Thrips, are minute insects well known to gardeners, differing from the Coleoptera in the nature of their metamorphoses, in which they resemble the Orthoptera and Hemiptera.

The Trichoptera, or Caddis worms, offer many points of resemblance to the Neuroptera, while in others they approach more nearly to the Lepidoptera. According to Westwood, the genus Phryganea "forms the connecting link between the Neuroptera and Lepidoptera."

The last of these small aberrant orders is that of the Aphaniptera, constituted for the family Pulicidæ. In their transformations, as in many other respects, they closely resemble the Diptera. Strauss Durckheim indeed said that "*la puce est un diptère sans ailes*." Westwood, however, regards it as constituting a separate order.

As indicated by the names of these orders, the structure of the wings affords extremely natural and convenient characters by which the various groups may be distinguished from one another. The mouthparts also are very important; and, regarded from this point of view, the Insecta have been divided into two series—the Mandibulata and Haustellata, or mandibulate and suctorial groups, between which the Collembola occupy an intermediate position. These two series are:

MANDIBULATA.	HAUSTELLATA.
Hymenoptera.	Lepidoptera.
Strepsiptera.	Diptera.
Coleoptera.	Aphaniptera.
Euplexoptera.	Hemiptera.
Orthoptera.	Homoptera.
Trichoptera?	
Thysanoptera?	

Again—and this is the most important from my present point of view—insects have sometimes been divided into two other series, according to the nature of their metamorphoses: "Heteromorpha," to use the terminology of Prof. Westwood, "or those in which there is no resemblance between the parent and the offspring; and Homomorpha, or those in which the larva resembles the imago, except in the absence of wings. In the former the larva is generally worm-like, of a soft and fleshy consistence, and furnished with a mouth, and often with six short legs attached in pairs to the three segments succeeding the head. In the Homomorpha, including the Orthoptera, Hemiptera, Homoptera, and certain Neuroptera, the body, legs, and antennæ are nearly similar in their form to those of the perfect insect, but the wings are wanting."

HETEROMORPHA.	HOMOMORPHA.
Hymenoptera.	Euplexoptera.
Strepsiptera.	Orthoptera.
Coleoptera.	Hemiptera.
Trichoptera.	Homoptera.
Diptera.	Thysanoptera.
Aphaniptera.	
Lepidoptera.	

Neuroptera.

But though the Homomorphic insects do not pass through such striking changes of form as the Heteromorphic, and are active throughout life, still it was until within the last few years generally (though erroneously) considered, that in them, as in the Heteromorpha, the life fell into four distinct periods;

those of (1) the egg, (2) the larva, characterized by the absence of wings, (3) the pupa with imperfect wings, and (4) the imago, or perfect insect.

The species belonging to the order Hymenoptera are among the most interesting of insects. To this order belong the gallflies, the sawflies, the ichneumons, and, above all, the ants and bees. We are accustomed to class the Anthropoid apes next to man in the scale of creation, but if we were to judge animals by their works, the chimpanzee and the gorilla must certainly give place to the bee and the ant. The larvæ of the sawflies, which live on leaves, and of the Siricidæ or long-tailed wasps, which feed on wood, are very much like caterpillars, having three pairs of legs, and in the former case abdominal prolegs as well: but in the great majority of Hymenoptera the larvæ are legless, fleshy grubs; and the various modes by which the females provide for, or secure to, them a sufficient supply of appropriate nourishment constitutes one of the most interesting pages of Natural History.

The species of Hymenoptera are very numerous; in England alone there are about 3,000 kinds, most of which are very small. In the pupa state they are inactive, and show distinctly all the limbs of the perfect insect, incased in distinct sheaths, and folded on the breast. In the perfect state they are highly organized and very active. The working ants and some few species are wingless, but the great majority have four strong membraneous wings, a character distinguishing them at once from the true flies, which have only one pair of wings.

The sawflies are so called because they possess at the end of the body a curious organ, corresponding to the sting of a wasp, but which is in the form of a fine-toothed saw. With this instrument the female sawfly cuts a slit in the stem or leaf of a plant, into which she introduces her egg. The larva much resembles a caterpillar, both in form and habits. To this group belongs the nigger, or black caterpillar of the turnip, which is often in sufficient numbers to do much mischief. Some species make galls, but the greater number of galls are formed by insects of another family, the Cynipidæ.

In the Cynipidæ the female is provided with an organ corresponding to the saw of the sawfly, but resembling a needle. With this she stings or punctures the surface of leaves, buds, stalks, or even roots of various plants. In the wound thus produced she lays one or more eggs. The effects of this proceeding, and particularly of the irritating fluid which she injects into the wound, is to produce a tumor or gall, within which the egg hatches, and on which the larva, a thick fleshy grub, feeds. In some species each gall contains a single larva; in others, many live together.

The oak supports several kinds of gallflies: one produces the well-known oak-apple, one a small swelling on the leaf resembling a currant, another a gall somewhat like an acorn, another attacks the root; the species making the bullet-like galls, which are now so common, has only existed for a few years in England; the beautiful little spangles so common in autumn on the under side of oak leaves are the work of another species, the Cynips longipennis. One curious point about this group is, that in some of the commonest species the females alone are known, no one yet having ever succeeded in finding a male.

Another great family of the Hymenoptera is that of the ichneumons; the females lay their eggs either in or on other insects, within the bodies of which the larvæ live. These larvæ are thick, fleshy, legless grubs, and feed on the fatty tissues of their hosts, but do not attack the vital organs. When full-grown, the grubs eat their way through the skin of the insect, and turn into chrysalides. Almost every kind of insect is subject to the attacks of these little creatures, which are no doubt useful in preventing the too great multiplication of insects, and especially of caterpillars. Some species are so minute that they actually lay their eggs within those of other insects. These parasites assume very curious forms in their larval state.

But of all the Hymenoptera, the group containing the ant, the bee, and the wasp is the most interesting. This is especially the case with the social species, though the solitary ones also are extremely remarkable. The solitary bee or wasp, for instance, forms a cell generally in the ground, places in it a sufficient amount of food, lays an egg, and closes the cell. In the case of bees, the food consists of honey; in that of wasps, the larva requires animal food, and the mother therefore places a certain number of insects in the cell, each species having its own special prey, some selecting small caterpillars, some beetles, some spiders. Cerceris bupresticida, as its name denotes, attacks beetles belonging to the genus Buprestis. Now if the Cerceris were to kill the beetle before placing it in the cell, it would decay, and the young larva, when hatched, would find only a mass of corruption. On the other hand, if the beetle were buried uninjured, in its struggles to escape it would be almost certain to destroy the egg. The wasp has, however, the instinct of stinging its prey in the centre of the nervous system, thus depriving it of motion, and let us hope of suffering, but not of life; consequently, when the young larva leaves the egg, it finds ready a sufficient store of wholesome food.

Other wasps are social, and, like the bees and ants, dwell together in communities. They live for one season, dying in autumn, except some of the females, which hibernate, awake in the spring, and form new colonies. These, however, do not, under ordinary circumstances, live through a second winter. One specimen which I kept tame through one spring and summer lived until the end of February, but then died. The larvæ of wasps are fat, fleshy, legless grubs. When full-grown they spin for themselves a silken covering, within which they turn into chrysalides. The oval bodies which are so numerous in ants' nests, and which are generally called ants' eggs, are really not eggs, but cocoons. Ants are very fond of the honey-dew which is formed by the Aphides, and have been seen to tap the Aphides with their antennæ, as if to induce them to emit some of the sweet secretion. There is a species of Aphis which lives on the roots of grass, and some ants collect these into their nests, keeping them, in fact, just as we do cows. Moreover, they collect the eggs in the autumn and tend them through the winter (when they are of no use) with the same care as their own, so as to have a supply of young Aphides in the spring. This is one of the most remarkable facts I know in the whole history of animal life. One species of red ant does no work for itself, but makes slaves of a black kind, which then do everything for their masters. The slave makers will not even put food into their own mouths, but would starve in the midst of plenty if they had not a slave to feed them. I found, however, that I could keep them in life and health for months if I gave them a slave for an hour or two in a week to clean and feed them.

Ants also keep a variety of beetles and other insects in their nests. Some of these produce a secretion which is licked by the ants as they do the honeydew; there are others, however, which have not yet been shown to be of any use to the ants, and yet are rarely, if ever, found, excepting in ants' nests. That the ants have some reason for tolerating their presence seems clear, because they readily attack any unwelcome intruder; but what that reason is, we do not yet know. If these insects are to be regarded as the domestic animals of the ants, then we must admit that the ants possess more domestic animals than we do.

M. Lespès, who regards these insects as true domestic animals, has recorded some interesting observations on the relations between one of them (Claviger Duvalii) and the ants (Lasius niger) with which it lives. This species of Claviger is never met with except in ants' nests, though, on the other hand, there are many communities of Lasius which possess none of these beetles; and M. Lespès found that when he placed Clavigers in a nest of ants which had none of their own, the beetles were immediately killed and eaten, the ants themselves being, on the other hand, kindly received by other communities of the same species. He concludes from these observations that some communities of ants are more advanced in civilization than others; the suggestion is no doubt ingenious, and the fact curiously resembles the experience of navigators who have endeavored to introduce domestic animals among barbarous tribes.

The order Strepsiptera are a small but very remarkable group of insects, parasitic on bees and wasps. The larva is minute, six-legged, and very active; it passes through its transformations within the body of the bee or wasp. The male and female are very dissimilar. The males are minute, very active, short-lived, and excitable, with one pair of large membraneous wings. The females, on the contrary, are almost motionless, and shaped very much like a bottle; they never quit the body of the bee, but only thrust out the top of the bottle between the abdominal rings of the bee.

In the order Coleoptera, the larvæ differ very much in form. The majority are elongated, active, hexapod, and more or less depressed; but those of the Weevils, of Scolytus, etc., which are vegetable feeders, and live surrounded by their food—as, for instance, in grain, nuts, etc.—are apod, white, fleshy grubs, not unlike those of bees and ants. The larvæ of the

Longicorns, which live inside trees, are long, soft, and fleshy, with six short legs. The Geodephaga, corresponding with the Linnæan genera Cicindela and Carabus, have six-legged, slender, carnivorous larvæ; those of Cicindela, which waylay their prey, being less active than the hunting larvæ of the Carabidæ. The Hydradephaga, or water-beetles, have long and narrow larvæ, with strong sickle-shaped jaws, short antennæ, four palpi, and six small eyes on each side of the head; they are very voracious. The larvæ of the Staphylinidæ are by no means unlike the perfect insect, and are found in similar situations; their jaws are powerful, and their legs moderately strong. The larvæ of the Lamellicorn beetles—cock-chafers, stag-beetles, etc.—feed on vegetable substances or on dead animal matter. They are long, soft, fleshy grubs, with the abdomen somewhat curved, and generally lie on their side. The larvæ of the Elateridæ, known as wireworms, are long and slender, with short legs. That of the glowworm (Lampyridæ) is not unlike the apterous female. The male glowworm, on the contrary, is very different. It has long, thin, brown wing-cases, and often flies into rooms at night, attracted by the light which it probably mistakes for that of its mate.

The metamorphoses of the Cantharidæ are very remarkable. The larvæ are at first active and hexapod. The Phytophaga are vegetable feeders, both as larvæ and in the perfect state. The larvæ are furnished with legs, and are not unlike the caterpillars of certain Lepidoptera.

The larva of Coccinella (the ladybird) is somewhat depressed, of an elongated ovate form, with a small head, and moderately strong legs. It feeds on Aphides.

Thus, then, we see that there are among the Coleoptera many different forms of larvæ. Macleay considered that there were five principal types.

The pupa of the Coleoptera is quiescent, and "the parts of the future beetle are plainly perceivable, being incased in distinct sheaths; the head is applied against the breast; the antennæ lie along the sides of the thorax; the elytra and wings are short and folded at the sides of the body, meeting on the under side of the abdomen; the two anterior pairs of legs are entirely exposed, but the hind pair are covered by wing-cases, the extremity of the thigh only appearing beyond the sides of the body." *

In the next three orders—namely, the Orthoptera (grasshoppers, locusts, crickets, walking-stick insects, cockroaches, etc.), Euplexoptera (earwigs), and Thysanoptera, a small group of insects well known to gardeners under the name of Thrips—the larvæ when they quit the egg already much resemble the mature form, differing, in fact, principally in the absence of wings, which are more or less gradually acquired, as the insect increases in size. They are active throughout life. Those specimens which have rudimentary wings are, however, usually called pupæ.

The Neuroptera present, perhaps, more differences in the character of their metamorphoses than any other order of insects. Their larvæ are generally

* Westwood's "Introduction."

active, hexapod little creatures, and do not vary from one another in appearance so much, for instance, as those of the Coleoptera, but their pupæ differ essentially; some groups remaining active throughout life, like the Orthoptera; while a second division have quiescent pupæ, which, however, in some cases, acquire more or less power of locomotion shortly before they assume the mature state; thus that of Raphidia, though motionless at first, at length acquires strength enough to walk, even while still inclosed in the pupa skin, which is very thin.

One of the most remarkable families belonging to this order is that of the Termites, or so-called white ants. They abound in the tropics, where they are a perfect pest, and a serious impediment to human development. Their colonies are extremely numerous, and they attack woodwork and furniture of all kinds, generally working from within, so that their presence is often unsuspected until it is suddenly found that they have completely eaten away the interior of some post or table, leaving nothing but a thin outer shell. Their nests, which are made of earth, are sometimes ten or twelve feet high, and strong enough to bear a man. One species, Termes lucifugus, is found in the south of France, where it has been carefully studied by Latreille. He found in these communities five kinds of individuals—(1) males; (2) females, which grow to a very large size, their bodies being distended with eggs, of which they sometimes lay as many as 80,000 in a day; (3) a form described by some observers as pupæ, but by others as neuters. These differ very much from the others, having a long, soft body without wings, but with an immense head, and very large, strong jaws. These individuals act as soldiers, doing apparently no work, but keeping watch over the nest and attacking intruders with great boldness. (4) Apterous eyeless individuals, somewhat resembling the winged ones, but with a larger and more rounded head; these constitute the greater part of the community, and, like the workers of ants and bees, perform all the labor, building the nest and collecting food. (5) Latreille mentions another kind of individual which he regards as the pupa, and which resembles the workers, but has four white tubercles on the back, where the wings afterward make their appearance. There is still, however, much difference of opinion among entomologists with reference to the true nature of these different classes of individuals. M. Lespès, who has studied the same species, describes a second kind of male and a second kind of female, and the subject, indeed, is one which offers a most promising field for future study.

Another interesting family of Neuroptera is that of the Ephemeræ, or Mayflies, so well known to fishermen. The larvæ are semi-transparent, active, six-legged little creatures, which live in water; having at first no gills, they respire through the general surface of the body. They grow rapidly and change their skin every few days. After one or two moults they acquire seven pairs of branchiæ, or gills, which are generally in the form of leaves, one pair to the segment. When the larvæ are about half grown, the posterior angles of the two posterior thoracic segments begin to elongate. These elongations become more and more marked with every change of skin. One morning, in the month of June, some years ago, I observed a full-grown larva, which had a glistening appearance, owing to the presence of a film of air under the skin. I put it under the microscope, and, having added a drop of water with a pipette, looked through the glass. To my astonishment, the insect was gone, and an empty skin only remained. I then caught a second specimen in a similar condition, and put it under the microscope, hoping to see it come out. Nor was I disappointed. Very few moments had elapsed, when I had the satisfaction of seeing the thorax open along the middle of the back; the two sides turned over; the insect literally walked out of itself, unfolded its wings, and in an instant flew up to the window. Several times since, I have had the pleasure of witnessing this marvelous change, and it is really wonderful how rapidly it takes place: from the moment when the skin first cracks, not ten seconds are over before the insect has flown away.

Another family of Neuroptera, the dragon-flies, or horse-stingers, as they are sometimes called, from a mistaken idea that they sting severely enough to hurt a horse, though in fact they are quite harmless, also spend their early days in the water. The larvæ are brown, sluggish, ugly creatures, with six legs. They feed on small water-animals, for which they wait very patiently, either at the bottom of the water or on some aquatic plant. The lower jaws are attached to a long folding rod; and when any unwary little creature approaches too near the larva, this apparatus is shot out with such velocity that the prey which comes within its reach seldom escapes. In their perfect condition, also, dragon-flies feed on other insects, and may often be seen hawking round ponds. The so-called ant-lions in many respects resemble the dragon-flies, but the habits of the larvæ are very dissimilar. They do not live in the water, but prefer dry places, where they bury themselves in the loose sand, and seize with their long jaws any small insect which may pass. The true ant-lion makes itself a round, shallow pit in loose ground or sand, and buries itself at the bottom. Any inattentive little insect which steps over the edge of this pit immediately falls to the bottom, and is instantaneously seized by the ant-lion. Should the insect escape, and attempt to climb up the side of the pit, the ant-lion is said to throw sand at it, knocking it down again.

One other family of Neuroptera which I must mention is the Hemerobiidæ. The perfect insect is a beautiful, lace-winged, very delicate, green creature, something like a tender dragon-fly, and with bright, green, touching eyes. The female deposits her eggs on leaves, not directly on the plant itself, but attached to it by a long white slender footstalk. The larva has six legs and powerful jaws, and makes itself very useful in destroying the hop-fly.

The insects forming the order Trichoptera are well known in their larval condition under the name of caddis worms. These larvæ are not altogether unlike caterpillars in form, but they live in water—which is the case with very few lepidopterous larvæ—and form for themselves cylindrical cases or tubes, built up of sand, little stones, bits of stick, leaves, or even shells. They generally feed on vegetable substances, but will also attack minute fresh-water animals. When full grown, the larva fastens its case to a stone, the stem of a plant, or some other fixed substance, and closes the two ends with an open grating of silken threads, so as to admit the free access of water, while excluding enemies. It then turns into a pupa which bears some resemblance to the perfect insect, "except that the antennæ, palpi, wings, and legs are shorter, inclosed in separate sheaths, and arranged upon the breast." The pupa remains quiet in the tube until nearly ready to emerge, when it comes to the surface, and in some cases creeps out of the water. It is not therefore so completely motionless as the pupæ of Lepidoptera.

The Diptera, or flies, comprise insects with two wings only, the hinder pair being represented by minute club-shaped organs called "haltères." Flies quit the egg generally in the form of fat, fleshy, legless grubs. They feed principally on decaying animal or vegetable matter, and are no doubt useful as scavengers. Other species, as the gadflies, deposit their eggs on the bodies of animals, within which the grubs feed, when hatched. The mouth is generally furnished with two hooks which serve instead of jaws. The pupæ of Diptera are of two kinds. In the true flies, the outer skin of the full-grown larva is not shed, but contracts and hardens, thus assuming the appearance of an oval brownish shell or case, within which the insect changes into a chrysalis. The pupæ of the gnats, on the contrary, have the limbs distinct and inclosed in sheaths. They are generally inactive, but some of the aquatic species continue to swim about.

One group of flies, which is parasitic on horses, sheep, bats, and other animals, has been called the Pupipara, because it was supposed that they were not born until they had arrived at the condition of pupæ. They come into the world in the form of smooth, ovate bodies, much resembling ordinary dipterous pupæ, but as Leuckart has shown, they are true, though abnormal, larvæ.

The next order, that of the Aphaniptera, is very small in number, containing only the different species of flea. The larva is long, cylindrical, and legless; the chrysalis is motionless, and the perfect insect is too well known, at least as regards its habits, to need any description.

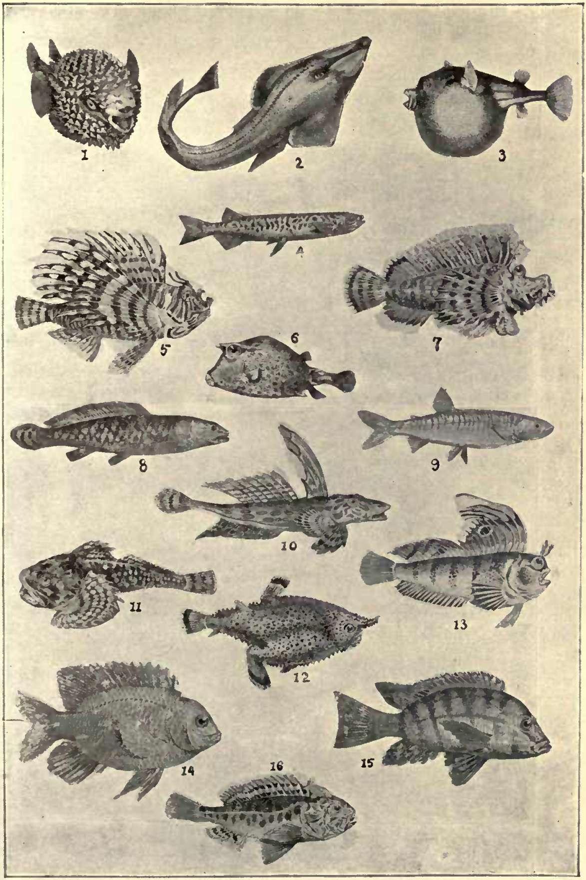
The Heteroptera, unlike the preceding orders of insects, quit the egg in a form differing from that of the perfect insect principally in the absence of wings, which are gradually acquired. In their metamorphoses they resemble the Orthoptera, and are active through life. The majority are dull in color, though some few are very beautiful. The species constituting this group, though very numerous, are generally small, and not so familiarly known to us as those of the other large orders, with indeed one exception, the well-known bug. This is not, apparently, an indigenous insect, but seems to have been introduced. The word is indeed used by old writers, but either as meaning a bugbear, or in a general sense, and not with reference to this particular insect. In Britain it never acquires wings, but is stated to do so sometimes in warmer climates. The Heteroptera can not exactly be said either to sting or bite. The jaws, of which, as usual among insects, there are two pairs, are like needles, which are driven into the flesh, and the blood is then sucked up by the lower lip, which has the form of a tube. This peculiar structure of the mouth prevails throughout the whole order; consequently their nutriment consists almost entirely of the juices of animals or plants. The Homoptera agree with the Heteroptera in the structure of the mouth, and in the metamorphoses. They differ principally in the front wings, which in Homoptera are membraneous throughout, while in the Heteroptera, the front part is thickened and leathery. As in the Heteroptera, however, so also in the Homoptera, some species do not acquire wings. The Cicada, celebrated for its chirp, and the lanthorn fly, belong to this group. So also does the so-called cuckoo-spit, so common in English gardens, which has the curious faculty of secreting round itself a quantity of frothy fluid which serves to protect it from its enemies. But the best known insects of this group are the Aphides or plant-lice; while the most useful belong to the Coccidæ, or scale insects, from one species of which we obtain the substance called lac, so extensively used in the manufacture of sealing-wax and varnish. Several species also have been used in dyeing, especially the cochineal insect of Mexico, a species which lives on the cactus. The male coccus is a minute, active insect, with four large wings; while the female, on the contrary, never acquires wings, but is very sluggish, broad, more or less flattened, and in fact, when full grown, looks like a small brown, red, or white scale.

The larvæ of the order Lepidoptera are familiar to us all under the name of caterpillars. The insects of this order in their larval condition are almost all phytophagous, and are very uniform both in structure and in habits. The body is long and cylindrical, consisting of thirteen segments; the head is armed with powerful jaws; the three following segments, the future prothorax, mesothorax, and metathorax, each bears a pair of simple articulated legs. Of the posterior segments, five also bear false or prolegs, which are short, unjointed, and provided with a number of hooklets. A caterpillar leads a dull and uneventful life; it eats ravenously and grows rapidly, casting its skin several times during the process, which generally lasts only a few weeks; though in some cases, as, for instance, that of the goat-moth, it extends over a period of two or three years, after which the larva changes into a quiescent pupa or chrysalis.

Fossil insects are, unfortunately, rare, there being but few strata in which the remains of this group are well preserved. Moreover, well-characterized Orthoptera and Neuroptera occur as early as the Devonian strata; Coleoptera and Hemiptera in the Coal-measures; Hymenoptera and Diptera in the Jurassic; Lepidoptera, on the contrary, not until the Tertiary. But although it appears from these facts that, as far as our present information goes, the Orthoptera and Neuroptera are the most ancient orders, it is not, I think, conceivable that the latter should have been derived from any known species of the former; on the other hand, the earliest known Neuroptera and Orthoptera, though in some respects less specialized than existing forms, are as truly and as well characterized insects as any now existing; nor are we acquainted with any earlier forms which in any way tend to bridge over the gap between them and lower groups, though, as we shall see, there are types yet existing which throw much light on the subject.

The stag-beetle, the dragon-fly, the moth, the bee, the ant, the gnat, the grasshopper—these and other less familiar types seem at first to have little in common. They differ in size, in form, in color, in habits, and modes of life. Yet the researches of entomologists, following the clew supplied by the illustrious Savigny, have proved not only that while differing greatly in details they are constructed on one common plan, but also that other groups, as, for instance, Crustacea (lobsters, crabs, etc.) and Arachnida (spiders and mites), can be shown to be fundamentally similar.

Thus, then, although it can be demonstrated that perfect insects, however much they differ in appearance, are yet reducible to one type, the fact becomes much more evident if we compare the larvæ. M. Brauer and I have pointed out that two types of larvæ, which I have proposed to call Campodea-form and Lindia-form, and which Packard has named Leptiform and Eruciform, run through the principal groups of insects.



Strange and Rare Fishes

1, Diodon; 2, Rhinobatus; 3, Tetrodon; 4, Galaxias; 5, Pterois; 6, Ostracion; 7, Pelor; 8, Amia; 9, Haplochiton; 10, Callionymus; 11, Cottus; 12, Malthe; 13, Blennius; 14, Pomacentrus; 15, Chromis; 16, Scorpæna

Let me say a word as to the general insect type. It may be described shortly as consisting of animals possessing a head, with mouth-parts, eyes, and antennæ; a many-segmented body, with three pairs of legs on the segments immediately following the head; with, when mature, either one or two pairs of wings, generally with caudal appendages.

Thus, then, we find in many of the principal groups of insects that, greatly as they differ from one another in their mature condition, when they leave the egg they more nearly resemble the typical insect type, consisting of a head, a three-segmented thorax, with three pairs of legs, and a many-jointed abdomen, often with anal appendages. Now, is there any mature animal which answers to this description? We need not have been surprised if this type, through which it would appear that insects must have passed so many ages since (for winged Neuroptera have been found in the carboniferous strata), had long ago become extinct. Yet it is not so. The interesting genus Campodea still lives; it inhabits damp earth, and closely resembles the larva of Chloëon, constituting, indeed, a type which occurs in many orders of insects. It is true that the mouth-parts of Campodea do not resemble either the strongly mandibulate form which prevails among the larvæ of Coleoptera, Orthoptera, Neuroptera, Hymenoptera, Lepidoptera; or the suctorial type of the Homoptera and Heteroptera. It is, however, not the less interesting or significant on that account, since its mouth-parts are intermediate between the mandibulate and haustellate types; a fact which seems to me most suggestive.

It appears, then, that there are good grounds for considering that the various types of insects are descended from ancestors more or less resembling the genus Campodea, with a body divided into head, thorax, and abdomen; the head provided with mouth-parts, eyes, and one pair of antennæ; the thorax with three pairs of legs; and the abdomen, in all probability, with caudal appendages.

If these views are correct, the genus Campodea must be regarded as a form of remarkable interest, since it is the living representative of a primeval type, from which not only the Collembola and Thysanura, but the other great orders of insects have derived their origin.

Since, then, individual insects are certainly in many cases developed from larvæ closely resembling the genus Campodea, why should it be regarded as incredible that insects as a group have gone through similar stages? That the ancestors of beetles under the influence of varying external conditions, and in the lapse of geological ages, should have undergone changes which the individual beetle passes through under our own eyes and in the space of a few days, is surely no wild or extravagant hypothesis. Again, other insects come from vermiform larvæ much resembling the genus Lindia, and it has been also repeatedly shown that in many particulars the embryo of the more specialized forms resembles the full-grown representatives of lower types. I conclude, therefore, that the Insecta generally are descended from ancestors resembling the existing genus Campodea, and that these again have arisen from others belonging to a type represented more or less closely by the existing genus Lindia.

Of course it may be argued that these facts have not really the significance which they seem to me to possess. It may be said that when Divine power created insects, they were created with these remarkable developmental processes. By such arguments the conclusions of geologists were long disputed. When God made the rocks, it was tersely said, He made the fossils in them. No one, I suppose, would now be found to maintain such a theory; and I believe the time will come when it will be generally admitted that the structure of the embryo, and its developmental changes, indicate as truly the course of organic development in ancient times as the contents of rocks and their sequence teach us the past history of the earth itself.

INSECTS: THEIR WINGS, STINGS, EARS, AND EYES

—PHILIP HENRY GOSSE

THE most perfect fliers in existence are insects. The swallow and the humming-bird are powerful on the wing, and rapid; but neither these nor any other "winged fowl" can be compared with many of the filmy-winged insects. The common house-fly, for example, will remain for hours together floating in the air beneath the ceilings of our dwelling-rooms, hovering and dancing from side to side, without effort and without fatigue. It has been calculated that in its ordinary flight the house-fly makes about 600 strokes with its wings every second, and that it is carried through the air a distance of five feet during that brief period. But, if alarmed, the velocity can be increased six or sevenfold, as every one must have observed, so as to carry the insect thirty or five-and-thirty feet in the second. In the same space of time, observes Mr. Kirby, a race-horse could clear only ninety feet, which is at the rate of more than a mile a minute. Our little fly, in her swiftest flight, will in the same space of time go more than the third of a mile. Now compare the infinite difference of the size of the two animals (ten millions of the fly would hardly counterpoise one racer), and how wonderful will the velocity of this minute creature appear! Did the fly equal the race-horse in size, and retain its present powers in the ratio of its magnitude, it would traverse the globe with the rapidity of lightning.

Bees, again, are accomplished masters of aerial motion. The humble-bees, notwithstanding their heavy bodies, are the most powerful fliers of this class. The same excellent entomologist tells us that they "traverse the air in segments of a circle, the arc of which is alternately to right and left. The rapidity of their flight is so great that, could it be calculated, it would be found, the size of the creature considered, far to exceed that of any bird, as has been proved by the observations of a traveler in a railway carriage proceeding at the rate of twenty miles an hour, which was accompanied, though the wind was against them, for a considerable distance by a humble-bee (Bombus subinterruptus), not merely with the same rapidity, but even greater, as it not infrequently flew to and fro about the carriage, or described zigzag lines in its flight. The aerial movements of the hive-bee are more distinct and leisurely."

You have doubtless often admired the noble dragon-fly, with its four ample and widespread wings of gauze, hawking in a green lane, or over a pool in the noon of summer. It sails, or rather shoots with arrowy fleetness hither and thither, now forward, now backward, now to the right, now to the left, without turning its body, but simply by the action of its powerful and elegant wings. Leeuwenhoek once saw an insect of this tribe chased by a swallow in a menagerie a hundred feet long. The dragon-fly shot along with such astonishing power of wing, to the right, to the left, and in all directions, that this bird of rapid flight and ready evolution was unable to overtake and capture it, the insect eluding every attempt, and being in general fully six feet in advance of the bird. A dragon-fly has been known to fly on board a ship at sea, the nearest land being the coast of Africa, five hundred miles distant, a fact highly illustrative of its power of wing.

It is a point of interest to know the structure of the organs by which such results are accomplished. Let us begin with the common fly. Well, we will borrow one of his wings for the lesson, and, putting it into the stage-forceps, we shall be able to turn it in any direction for observation beneath the microscope.

At first it seems a very thin, transparent membrane, of a shape between triangular and oval, with a few fine black lines running through it, and along one edge. But on bringing a greater magnifying power to bear on it, we see that the clear surface is covered with minute short stiff hairs, each of which has an expanded base. And still further, by delicate focusing, we find that there are two sets of these hairs, which come into view alternately, those of one row projecting upward toward our eye, those of the other downward. They are placed on both the upper and under surface, and are in fact appendages of two distinct membranes, applied to each other. There is some reason to believe that these hairs are delicate organs of touch communicating impressions through the skin to a sensitive layer beneath; at least such seems their function on the body, and we may judge from analogy that it is not different here.

The black lines are elastic, horny tubes, over which the membranes are spread and stretched, like the silk of an umbrella by its ribs. The upper membrane is firmly attached to the tubes (which are called nervures) ; the lower has but a slight adhesion, and is easily stripped from them. The nervures originate in the body, and diverge like a fan to various points of the tip, and to the upper and lower edges; some of them, however, terminate in the substance of the wing without reaching the edge, and some send off cross branches by which two are connected together. They generally maintain the same thickness throughout, but there are enlargements where the branches join the main trunks. These nervures are hollow, and are, during life, filled with a subtile fluid, which is supplied from the vessels of the body. They contain also ramifications of the exquisite spiral air-vessels.

In this wing of the bee all of these structures may be seen to greater advantage. Unlike the fly, which has but a single pair of wings, the bee has two pairs, of which the fore pair is the larger and more horny, the hinder pair seeming to be, as it were, cut out of the hinder and inner side of the fore ones. The two edges—the hinder edge of the fore pair and the front edge of the hind pair—then correspond, but it is necessary that, during flight, when the wings are expanded, the two wings on each side should *maintain* this relative position, neither overlapping the other, but together presenting one broad surface, wherewith to beat the air. There must be, therefore, some contrivance for locking together the two edges in question, which yet shall be capable of being unlocked at the pleasure of the animal; for the wings during repose slide over one another. This contrivance is furnished by a series of hairs or spines running along the front edge of the hindwing; they are bent up into strong semicircular hooks, arching outward, looking, under a high power, like the hooks on a butcher's stall. On the other hand, the margin of the forewing is strengthened, and is turned over with a shallow doubling, so as to make a groove into which the hooks catch; and thus, while the forewings are expanded, the hooks of the other pair are firmly locked in their doubled edge, while, as soon as flight ceases, and the wings are relaxed, there is no hindrance to the sliding of the front over the hind pair.

The wings of many insects are interesting on account of the organs with which they are clothed. A familiar example is furnished by the common gnat. There is the same general structure as before—two clear elastic membranes stretched over slender horny tubular nervures, and studded on both surfaces with short spine-like hairs, which in this case, however, are excessively numerous and minute. But along the nervures, and along other lines which run (generally) parallel with the front margin, and also along the whole margin, there are set long leaf-like scales of very curious appearance and structure.

There are, however, other insects which display these or similar appendages in far greater profusion, and in much variety of form and appearance. In the fissures of cliffs that border the seashore may often be found some wingless but active insects, which are endowed with the power of leaping in great perfection. From their hinder extremity being furnished with long projecting bristles, they are sometimes called bristle-tails, but naturalists designate the genus Machilis. If you can get one sufficiently still to examine it, you will be delighted with the lustre of its clothing, which appears dusted all over with a metallic powder of rich colors—red, brown, orange, and yellow, foiled by dull lead-gray in places.

If you touch one of these nimble leapers, though ever so slightly, you will see the result on your finger-ends, for they will be found covered with a thin stratum of the finest dust, which displays the colored metallic reflection seen on the insect. By touching one with a plate of glass, instead of your finger, you will get the same dust to adhere to this transparent medium, by applying which to the microscope you may at once discern the marvelous nature of the raiment with which the little creature is bedecked.

The dust is now seen to be composed of myriads of thin scales, mostly regular and symmetrical in their forms, though varying exceedingly among themselves in this respect. Some are heart-shaped, some shovel-shaped, some round, oval, elliptical, half round, half elliptical, long and narrow, sometimes irregular and unequal, and of various other indescribable outlines.

The beautiful and extensive order called Lepidoptera or scale-winged, *par excellence,* including the gay tribes of butterflies and moths, presents us with many exceedingly interesting varieties in these singular coverings.

Here are specimens from the pretty little white five-plume moth (Pterophorus), so common in meadows in summer. The general shape of the scales from the body and wings is that of a willow-leaf, some singly pointed, but more cut at the tip into two, three, or four notches. Those from the legs are longer and slenderer in proportion; and among the others from the wings there are some which take the form of hairs, which send forth one or more branches from one side, that form a very acute angle with the main stem. The scales proper are all marked with longitudinal lines, very minute and close, but they mostly bear a central band, and sometimes a marginal one on each side, of spots set in sinuous lines like the bands on a mackerel's back; these are probably composed of pigment-granules.

The hairs with which the bodies of moths are invested are essentially of the same character as the scales which clothe their wings. Here are examples from the glowing sides of the abdomen of that richly colored insect, the cream-spot tiger-moth (Arctia villica). You see they are simple scales, drawn out to an inordinate length and great tenuity; each has its quill-like footstalk, and we may trace on some of them the ribs and transverse dotting, while here we see all intermediate stages between the slenderest hair and the broadly ovate, bluntly pointed scales from the wings.

You are familiar, of course, with the brilliant little blue butterfly (Polyommatus Alexis) which dances and glitters in the sunshine on waste places in June. Among the scales of ordinary form which clothe the lovely little wings will occur one here and there of a different shape from the rest. Here you may see one; it is much smaller than the average; the footstalk is very long, and the shape of the entire scale is that of a battledoor. The ribs are rather few and coarse, and they have this peculiarity, that each rib swells at intervals into rounded dilatations, each of which has a minute black point in its centre. In some of these battledoor scales there is, near the lower part of the expansion, a crescent of minute pigment-grains.

Scales taken from the brilliant changeable blue-green patch in the hindwing of Papilio Paris, a fine Indian butterfly, have an interesting appearance. They are simply pear-shaped in outline, with few longitudinal ribs set far apart, and numerous strongly marked corrugations running across between them. That these are really elevations of the surface is well seen in some scales, even with transmitted light, and a high power; for the slopes of the wrinkles that face the light display the lustrous emerald reflection proper to the wing, while the transmitted color of the whole scale is a rich transparent red.

The dimensions of the scales do not bear any certain proportion to the size of the insect which is clothed with them; those from the broad wings of the noble Saturnia Atlas, for example, eight or nine inches in expanse, being exceeded in size by some from those of the little British muslin moth, an inch wide.

The little beetles which we are familiar with under the name of weevils, characterized by their long slender snouts, at the end of which they carry curiously folding antennæ, and which constitute the family Curculionidæ, are in many cases clothed with scales, to which they owe their colors and patterns. Several of British species display a green or silvery lustre, which under the microscope is seen to be produced by oval scales. But these are eclipsed by the splendor of many tropical species, especially that well-known one from South America which is called the diamond beetle, and scientifically

Entimus imperialis, from its unparalleled magnificence.

A piece of one of the wing-cases of this beetle is gummed to the slide now upon the stage. We look at it by reflected light with a magnifying power of 130 diameters. We see a black ground, on which are strewn a profusion of what look like precious stones blazing in the most gorgeous lustre. Topazes, sapphires, amethysts, rubies, emeralds seem here sown broadcast; and yet not wholly without regularity, for there are broad bands of the deep black surface, where there are no gems, and, though at considerable diversity of angle, they do all point with more or less precision in one direction, viz., that of the bands. These gems are flat transparent scales, very regularly oval in form, for one end is rather more pointed than the other; there is no appearance of a footstalk, and by what means they adhere I know not; they are evidently attached in some manner by the smaller extremity to the velvety black surface of the wing-case. The gorgeous colors seem dependent in some measure on the reflection of light from their polished surface, and to vary according to the angle at which it is reflected. Green, yellow, and orange hues predominate; crimson, violet, and blue are rare, except upon the long and narrow scales that border the suture of the wing-cases, where these colors are the chief reflected.

If you have ever thought on the subject, you have probably taken for granted that the various sounds produced by insects are voices uttered by their mouths. But it is not so. No insect has anything approaching to a voice. Vocal sounds are produced by the emission of air from the lungs variously modified by the organs of the mouth. But no insect breathes through its mouth; no air is expelled thence in a single species; it is a biting, or piercing, or sucking organ; an organ for the taking of food, or an organ for offence or defence; but never an organ of sound. The wings are in most cases the immediate causes of insect sounds.

There is a pretty little beetle (Clytus), not uncommon in summer in gardens, remarkable for the brilliant gamboge-yellow lines across its dark wing-cases, which makes a curious squeaking sound when you take it in your hand. You think it is crying; but if you carefully examine it with a lens while the noise is uttered, you will perceive that the cause is the grating of the thorax against the front part of the two wing-cases. Several other beetles produce similar sounds when alarmed, by rubbing the other end of the wing-sheaths with the tip of the abdomen. Many of those genera which feed on ordure and carrion do this.

But the noisiest of all insects are those of the classes Orthoptera and Homoptera, the crickets and grasshoppers, and the treehoppers. The locusts and grasshoppers, it appears, make use of their hindlegs in producing their crink. If you look at the grasshopper's leg, you will see that the thigh is marked with a number of transverse overlapping angular plates, and that the shank carries a series of short horny points along each side. The insect when it crinks brings the shank up to its thigh, and rubs both to and fro against the wing-sheaths, doing this by turns with the right and left legs, which causes the regular breaks in the sound.

In this case we may without hesitation conclude that the friction of the thigh-plates and shank-points on the rough edges of the wing-cases produces the musical vibration of the tense membrane, as rubbing a wet glass with the finger will yield a loud musical note.

The most elaborate contrivance for the production of sounds among the insect races, however, is found among the Cicadæ, celebrated in classical poetry as the very impersonations of song and eloquence.

Probably at some period of your life you have been stung by a bee or wasp. I shall take it for granted that you have, and that having tested the potency of these warlike insects' weapons with one sense, you have a curiosity to examine them with another. The microscope shall aid your vision to investigate the morbific implement.

This is the sting of the honey-bee. It consists of a dark brown horny sheath, bulbous at the base, but suddenly diminishing, and then tapering to a fine point. This sheath is split entirely along the inferior edge, and by pressure with a needle I have been enabled to project the two lancets, which commonly lie within the sheath. These are two slender filaments of the like brown horny substance, of which the centre is tubular, and carries a fluid, in which bubbles are visible. The extremity of each displays a beautiful mechanism, for it is thinned away into two thin blade-edges, of which one remains keen and knife-like, while the opposite edge is cut into several saw teeth pointing backward.

The lancets do not appear to be united with the sheath in any part, but simply to lie in its groove; their basal portions pass out into the body behind the sheath, where you see a number of muscle-bands crowded around them: these, acting in various directions, and being inserted into the lancets at various points, exercise a complete control over their movements, projecting or retracting them at their will. But each lancet has a singular projection from its back, which appears to act in some way as a guide to its motion, probably preventing it from slipping aside when darted forth, for the bulbous part of the sheath, in which these projections work, seems formed expressly to receive them.

Thus we see an apparatus beautifully contrived to enter the flesh of an enemy: the two spears finely pointed, sharp-edged, and saw-toothed, adapted for piercing, cutting, and tearing; the reversed direction of the teeth gives the weapon a hold in the flesh, and prevents it from being readily drawn out. Here is an elaborate store of power for the jactation of the javelins, in the numerous muscle-bands; here is a provision made for the precision of the impulse; and finally, here is a polished sheath for the reception of the weapons and their preservation when not in actual use. All this is perfect; but something still was wanting to render the weapons effective, and that something your experience has proved to be supplied.

The mere intromission of these points, incomparably finer and sharper than the finest needle that was ever polished in a Sheffield workshop, would produce no result appreciable to our feelings; and most surely would not be followed by the distressing agony attendant on the sting of a bee. We must look for something more than we have seen.

We need not be long in finding it. For here, at the base of the sheath, into which it enters by a narrow neck, lies a transparent pear-shaped bag, its surface covered all over, but especially toward the neck, with small glands set transversely. It is rounded behind, where it is entered by a very long and slender membraneous tube, which, after many turns and windings, gradually thickening and becoming more evidently glandular, terminates in a blind end.

This is the apparatus for preparing and ejecting a powerful poison. The glandular end of the slender tube is the secreting organ: here the venom is prepared; the remainder of the tube is a duct for conveying it to the bag, a reservoir in which it is stored for the moment of use. By means of the neck it is thrown into the groove at the moment the sting is projected, the same muscles, probably, that dart forward the weapon compressing the poison-bag and causing it to pour forth its contents into the groove, whence it passes on between the two spears into the wound which they have made.

A modification of this apparatus is found throughout a very extensive order of insects—the Hymenoptera; but in the majority of cases it is not connected with purposes of warfare. Wherever it occurs it is always confined to the female sex, or (as in the case of some social insects) to the neuters, which are undeveloped females. When it is not accompanied by a poison-reservoir it is ancillary to the deposition of the eggs, and is hence called an ovipositor, though in many cases it performs a part much more extensive than the mere placing of the ova.

A very wide field of observation, and one easily cultivated, is presented by the organs of sense in the insect races, and in particular by those curious jointed threads which proceed from the front or sides of the head, and which are technically called antennæ. These may sometimes be confounded with the palpi; for in a carnivorous beetle, for instance, both palpi and antennæ are formed of a number of oblong, polished hard joints, set end to end, like beads on a necklace. And it is probable there may be as much community in the function as in the form of these two sets of appendages; that both are the seats of some very delicate perceptive faculty allied to touch, but of which we can not, from ignorance, speak very definitely. It is likely, indeed, that sensations of a very variable character are perceived by them, according to their form, the degree of their development, and the habits of the species. It is not impossible, judging from the very great diversity which we find in the form and structure of these and similar organs in this immense class of beings, compared with the uniformity that prevails in the organs of sense bestowed on ourselves and other vertebrate animals, that a far wider sphere of perception is open to them than to us. Perhaps conditions that are appreciable to us only by the aid of the most delicate instruments of modern science may be appreciable to their acute faculties, and may govern their instincts and actions. Among such we may mention, conjecturally, the comparative moisture or dryness of the atmosphere, delicate changes in its temperature, in its density, the presence of gaseous exhalations, the proximity of solid bodies indicated by subtile vibrations of the air, the height above the earth at which flight is performed, measured barometrically, the various electrical conditions of the atmosphere; and perhaps many other physical diversities which can not be classed under sight, sound smell, taste, or touch, and which may be altogether unappreciable, and therefore altogether inconceivable, by us. It is probable, however, that the antennæ are the organs in which the sense of *hearing* is specially seated.

The forms which are assumed by the antennæ of insects are very diverse; and I can bring before you only a very small selection out of the mass. One of the most simple forms is that found in many beetles, as in this Carabus, for example. Here each antennæ is composed of eleven joints, almost exactly alike and symmetrical, each joint a horny body of apparently a long oval shape, polished on the surface, but not smooth, because covered with minute depressed lines, and clothed with shaggy hair. There is, however, a slight illusion in the appearance: it seems as if the dividing point of the joints were, as I have just said, at the termination of the oval, but when we look closely we see that the summit of each oval is, as it were, cut off by a line, and by comparing the basal joints with the others, we see that this line is the real division, that the summit of the oval really forms the bottom of the succeeding joint, and that the constricted part is no articulation at all. The first, or basal joint (called the scapus), and the second (called the pedicella), differ in form from the rest, here but slightly, but often considerably. The whole of the remaining joints are together termed the clavola.

There is a very extensive family of beetles known as Lamellicornes, because the antennal joints are singularly flattened and applied one over the other like the leaves of a book (lamella, a leaf).

But this structure is seen to still greater advantage in the much larger cockchafer, so abundant in May in some seasons. The insect widely expands them, evidently to receive impressions from the atmosphere; when alarmed, they are closed and withdrawn beneath the shield of the head, but on the first essay toward escape, or any kind of forward movement, the leaves are widely opened, and then, after an instant's pause to test the perceptions on the sensorium, away it travels.

But much more curious and beautiful are the antennæ of many moths, which often resemble feathers, particularly in the group Bombycina, of which the silkworm is an example; and in the male sex, which displays this structure more than the female.

This is the antenna of a large and handsome and not at all uncommon moth—the oak egger (Lasiocampa quercus). It consists of about seventy joints, so nearly alike in size and outline that the whole forms an almost straight rod, slightly tapering to the tip. Each joint, however, sends forth two long straight branches, so disposed that the pair make a very acute angle, and the whole double series of seventy on each side form a deep narrow groove. These two series of branches, being perfectly regular and symmetrical, impart to the antennæ the aspect of exquisite feathers.

It is, however, when we examine the elements of this structure in detail, using moderately high powers of enlargement, that we are struck with the elaborateness of the workmanship bestowed upon them. Each of the lateral branches is a straight rod, thick at its origin, whence it tapers to a little beyond its middle, and then thickens again to its tip. Here two horny spines project from it obliquely, one much stouter than the other, at such an angle as nearly to touch the tip of the succeeding branch.

Besides this, each branch is surrounded throughout its length with a series of short stiff bristles, very close-set, projecting horizontally (to the plane of the axis of the branch), and bent upward at the end candelabrum-fashion. The mode in which they are arranged is in a short spiral, which makes about forty-five whorls or turns about the axis; at least in the branches which are situated about the middle of the antennæ; for these diminish in length toward the extremity, bringing the feather to a rather abrupt point.

The entire surface of the branch gleams under reflected light with metallic hues, chiefly yellows and bronzy greens; which appear to depend on very minute and closely applied scales that overlap each other. The main stem of the feather—that is, the primary rod or axis—is somewhat sparsely clothed with scales of another kind, thin, oblong, flat plates, notched at the end, and very slightly attached by means of a minute stem at the base—the common clothing scales of the Lepidoptera.

We may acquire some glimpse of a notion why this remarkable development of antennæ is bestowed upon the male sex of this moth by an acquaintance with its habits. It has been long a practice with entomologists, when they have reared a female moth from the chrysalis, to avail themselves of the instincts of the species to capture the male. This sex has an extraordinary power of discovering the female at immense distances, and though perfectly concealed; and will crowd toward her from all quarters, entering into houses, beating at windows, and even descending chimneys, to come at the dear object of their solicitude. Collectors call this mode of procuring the male "sembling," that is "assembling," because the insects of the sex assemble at one point. It can not be practiced with all insects, nor even with all moths; those of this family, Bombycidæ, are in general available; and of these, none is more celebrated for the habit than the oak egger. The very individual whose antenna has furnished us with this observation was taken in this way; for having bred a female of this species, one evening I put her into a basket in my parlor. One male, the same evening, came dashing into the kitchen; but the next day, soon after noon, in the hot sunshine of August, no fewer than four more males came rapidly in succession to the parlor window, which was a little open, and, after beating about the panes a few minutes, found their way in, and made straightway for the basket, totally regardless of their own liberty.

It must be manifest to you that some extraordinary sense is bestowed upon these moths, or else some ordinary and well-known sense in extraordinary development. It may be smell; it may be hearing; but neither odor nor sound, perceptible by our dull faculties, is given forth by the females; the emanation is far too subtile to produce any vibrations on our sensorium, and yet sufficiently potent, and widely diffused, to call these males from their distant retreats in the hedges and woods.

The male gnat presents in its antennæ a pair of plumes of equal beauty, but of a totally different character. The pattern here is one of exceeding lightness and grace.

In the tribe of two-winged insects, which we term, *par excellence*, flies (Muscadæ), the antennæ are of peculiar structure. The common house-fly shall give us a good example. Here, in front of the head, is a shell-like concavity, divided into two by a central ridge. Just at the summit of this projection are the two antennæ, originating close together, and diverging as they proceed. Each antenna consists of three joints, of which the first is very minute, the second is a reversed cone, and the third, which is large, thick, and ovate, is bent abruptly downward immediately in front of the concavity. From the upper part of this third joint projects obliquely a stiff bristle or style, which tapers to a fine point. It is densely hairy throughout; and is more beset with longer hairs on two opposite sides, which decrease regularly in length from the base, making a wide and pointed plume.

Such are a few examples of what are presumed to be the *ears* of insects; let us now turn our attention to their *eyes*. And we can scarcely select a more brilliant, or a larger example, than is presented by this fine dragon-fly (Æshna), which I just now caught as it was hawking to and fro in my garden. How gorgeously beautiful are these two great hemispheres that almost compose the head, each shining with a soft satiny lustre of azure hue, surrounded by olive-green, and marked with undefined black spots, which change their place as you move the insect round!

Each of these hemispheres is a compound eye. I put the insect in the stage-forceps, and bring a low power to bear upon it with reflected light. You see an infinite number of hexagons, of the most accurate symmetry and regularity of arrangement. Into those which are in the centre of the field of view, the eye can penetrate far down, and you perceive that they are tubes; of those which recede from the centre, you discern more and more of the sides; while, by delicate adjustment of the focus, you can see that each tube is not open, but is covered with a convex arch of some glassy medium polished and transparent as crystal. There are, according to the computations of accurate naturalists, not fewer than 24,000 of these convex lenses in the two eyes of such a large species of dragon-fly as this. Every one of these 24,000 bodies represents a perfect eye; every one is furnished with all the apparatus and combinations requisite for distinct vision; and there is no doubt that the dragon-fly looks through them all. In order to explain this, I must enter into a little technical explanation of the anatomy of the organs, as they have been demonstrated by careful dissection.

The glassy convex plate or facet in front of each hexagon is a cornea, or corneule, as it has been called. Behind each cornea, instead of a crystalline lens, there descends a slender transparent pyramid, whose base is the cornea, and whose apex points toward the interior, where it is received and embraced by a translucent cup, answering to the vitreous humor. This, in its turn, is surrounded by another cup, formed by the expansion of a nervous filament arising from the ganglion on the extremity of the optic nerve, a short distance from the brain. Each lens-like pyramid, with its vitreous cup and nervous filament, is completely surrounded and isolated by a coat (the choroid) of dark pigment, except that there is a minute orifice or pupil behind the cornea, where the rays of light enter the pyramid, and one at the apex of the latter, where they reach the fibres of the optic nerve.

Each cornea is a lens with a perfect magnifying power. The focus of each cornea has been ascertained by similar experiments to be exactly equal to the length of the pyramid behind it, so that the image produced by the rays of light proceeding from any external object, and refracted by the convex cornea, will fall accurately upon the sensitive termination of the optic nerve-filament placed there to receive it.

The rays which pass through the several pyramids are prevented from mingling with each other by the isolating sheath of dark pigment; and no rays except those which pass along the axis of each pyramid can reach the optic nerve; all the rest being absorbed in the pigment of the sides. Hence it is evident that as no two corneæ on the rounded surface of the compound eye can have the same axis, no two can transmit a ray of light from the very same point of any object looked at; while, as each of the composite eyes is immovable, except as the whole head moves, the combined action of the whole 24,000 lenses can present to the sensorium but the idea of a single, undistorted, unconfused object, probably on somewhat of the same principle by which the convergence of the rays of light entering our two eyes gives us but a single stereoscopic picture.

The soft blue color of this dragon-fly's eyes—as also the rich golden reflections seen on the eyes of other insects, as the whameflies, and many other Diptera—is not produced by the pigment which I have alluded to, but is a prismatic reflection from the corneæ.

You would suppose that, having 24,000 eyes, the dragon-fly was pretty well furnished with organs of vision and surely would need no more; but you would be mistaken. It has three other eyes of quite another character.

If you look at the commissure or line of junction of the two compound eyes on the summit of the head, you will see just in front of the point where they separate and their front outlines diverge a minute crescent-shaped cushion of a pale-green color, at each angle of which is a minute antenna. Close to the base of each antenna there is set, in the black skin of the head that divides the green crescent from the compound eyes, a globose polished knob of crystal-like substance, much like the "bull's-eyes" or hemispheres of solid glass that are set in a ship's deck to enlighten the side-cabins. On the front side of the crescentic cushion there is a third similar glassy sphere, but much larger than the two lateral ones. What are these three spherules?

They are eyes, in no important respect differing from the individuals which compose the compound masses except that they are isolated. The shining glassy hemisphere is a cornea of hard transparent substance, behind which is situated a spherical lens, lodged in a kind of cup formed by an expansion of the optic nerve, and which is surrounded by a colored pigment-layer. You may study these simple eyes, or stemmata, as they are called, in many other insects, though they are not so universally present as the compound eyes. On the forehead of the honey-bee they are well seen, as three black shining globules, placed, as in the dragon-fly, in a triangle.

FAIRY FLIES.—Fred. Enock

If it were possible to obtain a reply from all living naturalists as to what first attracted their attention to insect life, I venture to think that seventy-five per cent or more of the replies would be: "The first sight of a living butterfly." How many of us (no matter what our specialty may now be) can look back to that time when, perhaps, a tortoise-shell flaunted its beauty before our youthful eyes, and we were drawn to it and fascinated by its gorgeous color, as it delicately sipped the nectar from a dandelion or thistle, gently opening and shutting its wings, spreading them as wide as possible so that every part should be seen! The colors and markings flashed before our enraptured gaze, and while we were held captive by its beauty, another still more beautiful butterfly—the peacock—sailed past and alighted close to the first, riveting our attention by the marvelously lovely "eyes" on its wings; and again another—this time a red admiral—in full sail bore down upon us, opened fire, and we surrendered, swearing allegiance for evermore to Atalanta and all her crew. Few boys could stand still and not be affected or influenced by such beauty. Such then has been, and will be, the foundation of our naturalists—"butterfly hunters" first, specialists later on.

As we are briefly running through the Hymenoptera our difficulties seem to increase, for with the next division, the Chalcididæ, we hardly know what to do, or to whom we can turn for assistance in naming these brilliantly spangled green and gold colored flies, whose "name is legion." The laborers in this field are indeed few, so much so that there is not a "specialist" even at the Natural History Museum, South Kensington.

Let us go back to one of those "neglected families" which have received but small attention. One reason for this want of attention is, no doubt, because of the extreme smallness of the members of this family, the largest being not more than one-twentieth of an inch long, whereas the smallest is less than one-eighty-fifth of an inch from head to tail. These insect atoms have been classed among the Chalcididæ by Haliday—the originator of the Mymaridæ—who first noticed them in 1833. Since that date Westwood has placed them among the Proctotrupidæ; and now Ashmead—author of American Proctotripidæ—has decided in favor of Haliday's arrangement, and in this I fully concur.

The fairy flies are, without doubt, among the many wonderful parasitic Hymenoptera, the most admirable in their exquisite structure, as well as in their habits and economy. All the species are egg parasites, and each species has its peculiar taste, selecting with unerring instinct the right kind of egg —generally that of an injurious insect—in which the female lays one of its own eggs, which in due time hatches or develops into an active maggot. This maggot feeds upon the contained fluids, and finds sufficient nutriment to bring it to full size, when it assumes the pupal stage. The fly, being matured, bites out a round piece of the eggshell large enough to allow it to escape. The most noticeable character in the fairy flies is the transverse line across the face a little above the insertion of the antennæ. The wings are devoid of all wing nerves, for the subcostal is so short and stumpy that the wing looks perfectly free. Both the upper and under surfaces of the wings are covered with minute hairs, and the margins of both wings are surrounded by long hairlike ciliæ.

Owing to the kindness of the authorities of Dublin Museum, I have been permitted to make a most exhaustive and critical examination of Haliday's type collection of British Mymaridæ, and though the hand of time and those of others have materially interfered with their original arrangement, the result has been most satisfactory to me. Although one or two of the most interesting types are absent, I have been enabled to re-establish Haliday's genus Panthus, which certain compilers had, for no apparent reason, ignored. I found two specimens still bearing the old labels, and after long and critical microscopic examination I saw that both were distinct from any others. I applied for and obtained permission to remove the carded specimens, and remount them in Canada balsam. This was successfully done, and on making a photo-micrograph the peculiar generic characters were brought out most distinctly. Some naturalists appear to imagine that a pocket lens will be sufficient to identify these species, but in an insect which is but a fiftieth or an eightieth of an inch long it is of absolute importance that every joint and detail should be examined under the microscope, and the relative proportion of each joint of the antennæ be compared with closely allied species—just as they are with all large Hymenoptera. The curve, too, of the delicate wings is a most important feature which must not be hurried over. This point leads me to speak of the immense superiority of photo-micrographs over drawings of these fairy flies. No matter how exact an enthusiastic naturalist may be in his endeavors, it is a physical impossibility for any one to follow out and reproduce the exact curve of these microscopic wings; and as the flies when properly prepared and "set" in Canada balsam lend themselves peculiarly to photo-micrography, it is wise to take advantage of this. The details can afterward be drawn to a much larger scale. It is my intention to do this with every species which I have collected during the past twenty-five years, and of which I have a very large number, far exceeding those known to science. The illustrations accompanying this short article will, I think, show what exceedingly good subjects the fairy flies are for photo-micrographs.

Since Haliday's arrangement of the British Mymaridæ, elucidated by Francis Walker, no new species have been recorded, the genera numbering eleven, the species, thirty-five, as follows, viz.:

Ooctonus, four species	*Mymar*, one species
Gonatocerus, five species	*Cosmocoma*, eight species
Alaptus, two species	*Caraphractus*, one species
Litus, one species	*Anaphes*, seven species
Eustochus, one species	*Anagrus*, four species
Camptoptera, one species	

Of these I have found representatives of all, and a few notes may not be uninteresting to those who desire to search for these fairy flies.

Ooctonus. Of this genus I have not found very many specimens. It is thick-set, and least like a fairy. Unfortunately, Haliday did not publish any detailed account of his captures, but from the fact of his naming one (plentifully represented in his collection) Ooctonus hemipterus, it is just possible it may be parasitic in eggs of bugs.

Gonatocerus is, perhaps, as plentiful as any in the London district. It is a constant visitor to my garden, though I have failed to discover its nidus.

Alaptus minimus and fusculus have long been known to me. The first-named is not more than one-seventy-second of an inch long, with a sessile abdomen. Its wings are somewhat hatchet shaped, with peculiar enlargements at the base of the inner margin. The lower wings have a crimped appearance, arising from the mackerel marking. This, and in fact all the family, are to be found running up the glass in a greenhouse, especially on the window facing east. Alaptus fusculus is one of the first to appear in spring—its peculiar jerky gait will at once reveal its identity. Of this species I have bred hundreds from the eggs of a psocid (Stenopscocus cruciatus), an insect much like a common aphis, but very active and shy, having a decided objection to being watched. But "all good things come to those who know how to wait," and wait he must for hours, days, months, and years before the life history of a single species is made out. Haliday mentions that

Polynema (Cosmocoma) destroys the eggs of the cabbage butterfly. I read this twenty-five years ago, but I have never yet found one egg "struck." Stenopscocus lays its eggs on the leaves of various shrubs and trees. I have found them on lime, oak, sycamore, hawthorn, and ivy. They are laid in patches of ten to twenty, the female psocid carefully weaving a silken covering in an endeavor to protect them from the attacks of enemies; but, alas! who would imagine a fairy fly to be an enemy? Yet its microscopic size enables it to pass unnoticed, and also permits its passing beneath the silken screen, and, once there, woe betide the psocid's eggs! for the busy fairy taps one with her clubbed antennæ, mounts to the summit, and then lets down the ovipositor until the barbed tip touches the surface of the fresh-laid egg (it must be fresh). Now by carefully focusing a good magnifier, we can observe the fairy taking a firm hold of the surface of the egg with the two curved tips of each of her exquisitely formed toes! Next we note that pressure is being put upon the barbed ovipositor. The antennæ are pressed firmly to the surface, and impress the observer with the fact that some very serious business is in hand. Eleven minutes have passed without any sign of a move, when just after eleven and a quarter the ovipositor positively bumps through the shell. There is another serious pause, and then up go the clubbed antennæ, and very carefully the ovipositor is withdrawn until it slips back between the sheaths. The fairy turns round, and with saliva from her mouth seals up the incision.

Another egg is ascended, bored, and stored with an egg—and so on until the whole batch of twenty has been struck, and all chance of any psocid emerging utterly ruined. I kept the first batch of eggs which I had seen struck in October until the following year, when, as the warm days of April arrived, I carefully examined them, until one eventful day I observed one of the eggs had a tiny hole in it. On placing it under the microscope I saw a pair of mandibles busily at work nibbling away the egg-shell, until at last the hole was large enough to admit of the head being thrust through. After many efforts the antennæ were freed, followed by the first pair of legs; then, with this additional leverage at command, the thorax was lifted out, the second pair of legs and part of the wings following, and after much apparently painful effort the third and last pair of legs was withdrawn, enabling the fairy to walk out, and to free those most exquisitely delicate wings without a hitch. Now, taking a firm grip on the empty eggshell, the fairy went through her toilet. Not a hair or spine escaped attention—each and every part of this microscopic marvel received the utmost attention; every hair forming the lovely marginal fringe was brushed out and arranged in exact order. The wings were raised several times to try them, and then away this atom of perfection flew. Since my first seeing the ovipositor of a fairy fly I have dissected many struck eggs, and in less than a minute had the germ (laid by the fairy fly) under my microscope, and watched it grow, and the cells divide again and again in such a marvelous manner that I have been lost in wonderment or simply overcome. Flesh and blood is not strong enough to carry on such watchings too long, but the fascination is so great that time after time have I watched the mysterious changes taking place—various organs being formed under my eyes—the active larva gradually losing all its activity until it appears in pupal form, and then new limbs and organs seem to be evolved from nothing at all.

The next genus, Litus, is a peculiar one. Its one representative, Litus cynipseus, much resembles a flea in color and form. It is the only fairy fly that takes its time in walking. I have never seen it in a hurry, neither have I ever seen the male—and the female is not a plentiful species.

Eustochus is distinguished by having a deeply marked suture across the club of the antennæ, and though Haliday mentions but one species, I have found over a dozen; in fact, of this genus I can always find specimens anywhere—on windows, in greenhouses, in railway carriages, besides sweeping them up from grass and all kinds of herbage. I have also seen and caught them flying, and have obtained many specimens from spiders' webs.

Mymar pulchellus is, without doubt, the most extraordinary of the whole family. My first specimen I caught in a spider's web when living near Finsbury Park. It was very much held by viscid globules, but after many hours' work appeared in Canada balsam a splendid mount. No insect has exercised my power of thought more than this one; but its life history remains a mystery still, though I imagine I am within measurable distance of discovering its nidus. The posterior wings are abnormal —mere bristles—and yet they are of immense service when hooked into the anterior ones, the black specks just before the tips of these bristle-like wings being the three hooklets.

The next representative, Cosmocoma, is Haliday's Polynema, which, he states, affects the eggs of the cabbage butterfly. C. fumipennis is of the most strikingly beautiful character. I once saw the male of this, but it was on the glass outside the greenhouse, while I was inside and the door was locked. My feelings at that moment can be better imagined than described.

Caraphractus cinctus has received a good deal of attention and notoriety from the fact that in 1862 Sir John Lubbock discovered that it was aquatic in its habits, using its wings for swimming under water. It was christened Polynema natans by the worthy discoverer of its natatorial habits; but in 1896 it fell to my lot to prove it to be identical with Haliday's Caraphractus.

Anaphes is found in almost any garden, and is frequently confounded with Eustochus, but the solid club is an unfailing character. It is also somewhat larger than Eustochus.

Anagarus contains many species of very delicate yellow fairy flies, always present in gardens and about ponds—in fact, almost everywhere. I have been again fortunate in discovering the life history of several species belonging to this genus. One is parasitic in eggs of dragon-flies, and three others in different kinds of eggs of frog-hoppers, which have for over thirty years eluded my search.

One more genus remains to be noticed, and it is the most fairy-like of all the Mymaridæ, viz., Camptoptera papaveris. It is the smallest of the family, the female being but one-eighty-fifth of an inch long. Mystery surrounds this gem, and yet it is most plentiful in certain localities. The male, of which I have only taken two specimens, measures just one-ninety-second of an inch from head to tail, and yet is absolutely perfect in every part.

INSECT TRANSFORMATIONS.—Andrew Wilson

MOST people are aware, as a piece of commonplace knowledge, that many animals, before arriving at their mature or adult state, undergo a series of changes in form, of a more or less complete character. To such a series of changes the naturalist applies the term "metamorphosis"; and the study of the disguises which an animal may in this way successively assume forms one of the most interesting and fascinating subjects that can attract the notice of the observer.

The great insect-class presents us with the most familiar examples of these changes, and the butterflies and moths exemplify metamorphosis in its most typical aspect. Thus we know that from the egg of the butterfly, deposited by the short-lived parent upon the leaves of plants, a crawling grub-like creature is first developed. This form we name the "larva" or "caterpillar"; and if we might fail to recognize its relationship to the bright denizen of the air as far as outward appearance is concerned, we might also be at a loss to reconcile its internal structure with that of the perfect butterfly. Thus the latter is winged; possesses a mouth and digestive system, adapted for the reception and assimilation of flower-juices; and wholly differs in structure and habits from its worm-like progeny. The caterpillar is provided with a mouth furnished with jaws, and adapted for biting or mastication; its digestive system presents a type differing widely from that of the perfect form; and its crawling, terrestrial habits appear in strong contrast to the light and ethereal movements of its parent.

The life of this larva may be accurately described as one devoted solely to its nourishment. Its entire existence, while in the caterpillar state, is one long process of continuous eating and devouring. By means of its jaws it nips and destroys the young leaves of plants, much to the gardener's annoyance; and so rapidly does its body increase in size, that the first skin with which its body is provided soon cracks and bursts like a tight-fitting coat, and a process of moulting ensues. As the result of this process the larva emerges, clad in a new skin, adapted to the increased size of its body. This second skin may similarly become inadequate to accommodate its ever-increasing growth, and a second process of moulting produces in turn a new investment. In this way the caterpillar may change its coat many times—twenty-one moultings have been counted in the development of the May-flies—and on arriving at the close of its larval stage of existence, may present a very great increase in size, as compared with the dimensions it presented at the beginning of its life.

But, sooner or later, the caterpillar appears to sicken, and to become quiescent. Its former state of activity is exchanged for one of lethargy, from which it awakes to begin an operation of a novel and different nature from that in which it has been previously engaged. It begins to spin a delicate silky thread by means of a special apparatus, situated in the head, and which consists of silk-glands and of an organ named the "spinneret." Within the silken case or "cocoon" which it thus constructs with the thread of the spinneret, the caterpillar-body is soon inclosed; the first stage of its existence comes to an end; and the second or cocoon stage, marked by outward quiescence and apparent rest, becomes known to us as that of the "pupa," "chrysalis," or "nymph."

Although outwardly still, and although all the former activity appears to have been exchanged for a state of dull repose, changes of active kind, and of marvelous extent, are meanwhile proceeding within the cocoon or pupa-case. The elements of the caterpillar's form are being gradually disintegrated or broken down, and built up anew in the form and image of the adult butterfly. Old textures and garments are being exchanged for new ones; particle by particle the outward and inward structures of the larva are being replaced by others proper to the mature being; and in due course, and after a longer or shorter period, the cocoon is ruptured, and the perfect form emerges—a bright and beautiful creature, furnished with wings and active senses, and rejoicing in the exercise of its new-born functions amid the sunlight and the flowers.

Such is an outline of the familiar process by which the larva or caterpillar of the butterfly becomes transformed or developed, to form the "imago" or perfect and adult form. And if we review the stages exemplified in the process, we shall be able to detect in each an obvious harmony and correspondence both with the preceding and with the succeeding stage. Thus we find that the life of the perfect and mature insect is at the best of a comparatively short and transient nature, and its energies are directed chiefly to reproduction—to the deposition of eggs, from which new individuals will, in due course, be reproduced. The larval stage, on the contrary, is devoted to nutrition; to the laying up, as it were, of a store of nourishment, sufficient to last throughout the lifetime of the being, and to sustain it while its adult functions are being performed.

Indeed, the entire lifetime of the higher insect may be divided into, or comprised within, two distinct periods. The first of these latter is the nutritive period, represented by the caterpillar-state, when the nutrition of the body is mainly provided for; and the second period, no less defined than the first, is included in the life of the perfect form, which is devoted to reproducing the species. This last we might therefore term the reproductive period of insect-life.

All insects, however, do not exemplify "metamorphosis" in so perfect a manner as does the butterfly. The beetles, flies, bees, etc., and many other insects, undergo a process of metamorphosis essentially resembling that of the butterfly; the characteristic feature of this form of development being that while the caterpillar stage is passed in activity, the pupa or chrysalis is quiescent; and from this resting-pupa the active, winged insect comes forth. The dragon-flies, crickets, grasshoppers, and their allies, undergo, on the other hand, a less perfect series of changes than the foregoing insects. The young grasshopper, on leaving the egg, bears first a close resemblance to the perfect insect. It is, further, not of worm-like conformation, and in these two points differs from the larva of the other forms. Then, thirdly, it does not inclose itself in a cocoon-case, but passes its chrysalis stage in a free and active condition. In this respect it again differs from the butterfly chrysalis; and its perfect form is attained simply by the development of the wings. So that, in reality, the chief difference between the young and the perfect form of the grasshopper consists in the non-development in the former of the wings, which are thus characteristic of the adult form.

The dragon-flies illustrate an essentially similar kind of metamorphosis, but also exemplify differences in the details of their development. The young of the dragon-fly are active creatures, inhabiting the water of pools; the eggs from which they are produced having been deposited by the parent in bunches on the leaves of water-plants. The larvæ are of brownish color, and possess six legs, and a peculiar apparatus of jaws, consisting of a pair of nippers attached to a movable, rod-like stem. This apparatus can be folded upon the head, when it gives to the larva the appearance of being masked, and hence the name of "mask" which has been applied to this structure. But on the approach of some unwary insect, the jaws can be rapidly extended to seize the unfortunate victim, and convey it to the mouth of its captor. The dragon-fly's young are thus purely aquatic in habits, and propel themselves along by ejecting water, which has been used in breathing, from the posterior extremity of the body.

Having arrived at the close of its chrysalis-stage of development—the chrysalis differing from the larva simply in its greater size, and in the development of the wings and perfect body within the pupa-skin—the insect at length fixes its body to some water-plant. The pupa-skin next splits along the back, and the mature, winged insect slowly emerges therefrom. The crumpled wings soon dry, and acquire their normal consistence; and the dragon-fly, freed from the trammels of a mundane existence, mounts into the air, and "revels in the freedom of luxury and light." Tennyson has aptly described this change in his lines:

> To-day I saw the dragon-fly
> Come from the wells where he did lie.
>
> An inner impulse rent the veil
> Of his old husk: from head to tail
> Came out clear plates of sapphire mail.
>
> He dried his wings: like gauze they grew:
> Thro' crofts and pastures wet with dew
> A living flash of light he flew.

In these latter instances, as in the case of the butterfly, the nutrition of the insects has been proceeding during the earlier stages of life, and has been fitting them for entering upon the final part of their existence, which may extend for a longer or shorter period, but which is mainly devoted to the continuation of the species. The time occupied in the development of insects varies greatly in different groups. Cold and damp appear to delay this process. The chrysalis of a butterfly has been kept for two years in an icehouse, without undergoing development; while on removal to a warm place it became transformed into the winged insect. The cockchafer occupies three years in its development, the duration of life in its perfect state being probably only a single year.

STRUGGLE FOR EXISTENCE. — CHARLES DARWIN

AMONG organic beings in a state of nature there is some individual variability: indeed I am not aware that this has ever been disputed. It is immaterial for us whether a multitude of doubtful forms be called species or sub-species or varieties; what rank, for instance, the two or three hundred doubtful forms of British plants are entitled to hold, if the existence of any well-marked varieties be admitted. But the mere existence of individual variability and of some few well-marked varieties, though necessary as the foundation for the work, helps us but little in understanding how species arise in nature. How have all those exquisite adaptations of one part of the organization to another part, and to the conditions of life, and of one organic being to another being, been perfected? We see these beautiful co-adaptations most plainly in the woodpecker and the mistletoe; and only a little less plainly in the humblest parasite which clings to the hairs of a quadruped or feathers of a bird; in the structure of the beetle which dives through the water; in the plumed seed which is wafted by the gentlest breeze; in short, we see beautiful adaptations everywhere and in every part of the organic world.

Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species, which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All these results follow from the struggle for life. Owing to this struggle, variations, however slight and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection, in order to mark its relation to man's power of selection. But the expression often used by Mr. Herbert Spencer of the Survival of the Fittest is more accurate, and is sometimes equally convenient.

The elder De Candolle and Lyell have largely and philosophically shown that all organic beings are exposed to severe competition. In regard to plants, no one has treated this subject with more spirit and ability than W. Herbert, Dean of Manchester, evidently the result of his great horticultural knowledge. Nothing is easier than to admit in words the truth of the universal struggle for life, or more difficult—at least I have found it so—than constantly to bear this conclusion in mind. Yet unless it be thoroughly ingrained in the mind, the whole economy of nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood. We behold the face of nature bright with gladness, we often see superabundance of food; we do not see or we forget that the birds which are idly singing round us mostly live on insects or seeds, and are thus constantly destroying life; or we forget how largely these songsters, or their eggs, or their nestlings, are destroyed by birds and beasts of prey; we do not always bear in mind that, though food may be now superabundant, it is not so at all seasons of each recurring year.

I should premise that I use this term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals, in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which only one on an average comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for, if too many of these parasites grow on the same tree, it languishes and dies. But several seedling mistletoes, growing close together on the same branch, may more truly be said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on them; and it may metaphorically be said to struggle with other fruit-bearing plants, in tempting the birds to devour and thus disseminate its seeds. In these several senses, which pass into each other, I use for convenience' sake the general term of Struggle for Existence.

A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species.

There is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate, in less than a thousand years, there would literally not be standing-room for his progeny. Linnæus has calculated that if an annual plant produced only two seeds—and there is no plant so unproductive as this—and their seedlings next year produced two, and so on, then in twenty years there would be a million plants. The elephant is reckoned the slowest breeder of all known animals, and I have taken some pains to estimate its probable minimum rate of natural increase; it will be safest to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old; if this be so, after a period of from 740 to 750 years there would be nearly nineteen million elephants alive, descended from the first pair.

But we have better evidence on this subject than mere theoretical calculations; namely, the numerous recorded cases of the astonishingly rapid increase of various animals in a state of nature, when circumstances have been favorable to them during two or three following seasons. Still more striking is the evidence from our domestic animals of many kinds which have run wild in several parts of the world; if the statements of the rate of increase of slow-breeding cattle and horses in South America, and latterly in Australia, had not been well authenticated, they would have been incredible. So it is with plants; cases could be given of introduced plants which have become common throughout whole islands in a period of less than ten years. In such cases, and endless others could be given, no one supposes that the fertility of the animals or plants has been suddenly and temporarily increased in any sensible degree. The obvious explanation is that the conditions of life have been highly favorable, and that there has consequently been less destruction of the old and young, and that nearly all the young have been enabled to breed. Their geometrical ratio of increase, the result of which never fails to be surprising, simply explains their extraordinarily rapid increase and wide diffusion in their new homes.

In a state of nature almost every full-grown plant annually produces seed, and among animals there are very few which do not annually pair. Hence we may confidently assert that all plants and animals are tending to increase at a geometrical ratio—that all would rapidly stock every station in which they could anyhow exist—and that this geometrical tendency to increase must be checked by destruction at some period of life. Our familiarity with the larger domestic animals tends, I think, to mislead us: we see no great destruction falling on them, but we do not keep in mind that thousands are annually slaughtered for food, and that in a state of nature an equal number would have somehow to be disposed of.

The only difference between organisms which annually produce eggs or seeds by the thousand, and those which produce extremely few, is, that the slow-breeders would require a few more years to people, under favorable conditions, a whole district, let it be ever so large. The condor lays a couple of eggs and the ostrich a score, and yet in the same country the condor may be the more numerous of the two; the Fulmar petrel lays but one egg, yet it is believed to be the most numerous bird in the world. One fly deposits hundreds of eggs, and another, like the hippobosca, a single one; but this difference does not determine how many individuals of the two species can be supported in a district. A large number of eggs is of some importance to those species which depend on a fluctuating amount of food, for it allows them rapidly to increase in number. But the real importance of a large number of eggs or seeds is to make up for much destruction at some period of life; and this period in the great majority of cases is an early one. If an animal can in any way protect its own eggs or young, a small number may be produced, and yet the average stock be fully kept up; but if many eggs or young are destroyed, many must be produced, or the species will become extinct. It would suffice to keep up the full number of a tree, which lived on an average for a thousand years, if a single seed were produced once in a thousand years, supposing that this seed were never destroyed, and could be insured to germinate in a fitting place.

So that, in all cases, the average number of any animal or plant depends only indirectly on the number of its eggs or seeds.

In looking at Nature, it is most necessary to keep the foregoing considerations always in mind—never to forget that every single organic being may be said to be striving to the utmost to increase in numbers; that each lives by a struggle at some period of its life; that heavy destruction inevitably falls either on the young or old, during each generation or at recurrent intervals. Lighten any check, mitigate the destruction ever so little, and the number of the species will almost instantaneously increase to any amount.

The causes which check the natural tendency of each species to increase are most obscure. Look at the most vigorous species; by as much as it swarms in numbers, by so much will it tend to increase still further. We know not exactly what the checks are even in a single instance. Nor will this surprise any one who reflects how ignorant we are on this head, even in regard to mankind, although so incomparably better known than any other animal. Eggs or very young animals seem generally to suffer most, but this is not invariably the case. With plants there is a vast destruction of seeds, but, from some observations which I have made, it appears that the seedlings suffer most from germinating in ground already thickly stocked with other plants. Seedlings, also, are destroyed in vast numbers by various enemies; for instance, on a piece of ground three feet long and two wide, dug and cleared, and where there could be no choking from other plants, I marked all the seedlings of our native weeds as they came up, and out of 357 no less than 295 were destroyed, chiefly by slugs and insects. If turf which has long been mown, and the case would be the same with turf closely browsed by quadrupeds, be let grow, the more vigorous plants gradually kill the less vigorous, though fully grown plants; thus out of twenty species growing on a little plot of mown turf (three feet by four) nine species perished, from the other species being allowed to grow up freely.

The amount of food for each species of course gives the extreme limit to which each can increase; but very frequently it is not the obtaining food, but the serving as prey to other animals, which determines the average numbers of species. Thus, there seems to be little doubt that the stock of partridges, grouse, and hares on any large estate depends chiefly on the destruction of vermin. If not one head of game were shot during the next twenty years in England, and, at the same time, if no vermin were destroyed, there would, in all probability, be less game than at present, although hundreds of thousands of game animals are now annually shot. On the other hand, in some cases, as with the elephant, none is destroyed by beasts of prey; for even the tiger in India most rarely dares to attack a young elephant protected by its dam.

Climate plays an important part in determining the average numbers of a species, and periodical seasons of extreme cold or drought seem to be the most effective of all checks. I estimated (chiefly from the greatly reduced numbers of nests in the spring) that the winter of 1854-55 destroyed four-fifths of the birds in my own grounds; and this is a tremendous destruction, when we remember that ten per cent is an extraordinarily severe mortality from epidemics with man. The action of climate seems at first sight to be quite independent of the struggle for existence; but in so far as climate chiefly acts in reducing food, it brings on the most severe struggle between the individuals, whether of the same or of distinct species, which subsist on the same kind of food. Even when climate, for instance extreme cold, acts directly, it will be the least vigorous individuals, or those which have got least food through the advancing winter, which will suffer most. When we travel from south to north, or from a damp region to a dry, we invariably see some species gradually getting rarer and rarer, and finally disappearing; and the change of climate being conspicuous, we are tempted to attribute the whole effect to its direct action. But this is a false view; we forget that each species, even where it most abounds, is constantly suffering enormous destruction at some period of its life, from enemies or from competitors for the same place and food; and if these enemies or competitors be in the least degree favored by any slight change of climate, they will increase in numbers; and as each area is already fully stocked with inhabitants, the other species must decrease. When we travel southward and see a species decreasing in numbers, we may feel sure that the cause lies quite as much in other species being favored as in this one being hurt. So it is when we travel northward, but in a somewhat lesser degree, for the number of species of all kinds, and therefore of competitors, decreases northward; hence in going northward, or in ascending a mountain, we far oftener meet with stunted forms, due to the *directly* injurious action of climate, than we do in proceeding southward or in descending a mountain. When we reach the Arctic regions or snow-capped summits, or absolute deserts, the struggle for life is almost exclusively with the elements.

That climate acts in main part indirectly by favoring other species, we clearly see in the prodigious number of plants which in our gardens can perfectly well endure our climate, but which never become naturalized, for they can not compete with our native plants nor resist destruction by our native animals.

When a species, owing to highly favorable circumstances, increases inordinately in numbers in a small tract, epidemics—at least, this seems generally to occur with our game animals—often ensue; and here we have a limiting check independent of the struggle for life. But even some of these so-called epidemics appear to be due to parasitic worms, which have from some cause, possibly in part through facility of diffusion among the crowded animals, been disproportionally favored: and here comes in a sort of struggle between the parasite and its prey.

On the other hand, in many cases, a large stock of individuals of the same species, relatively to the numbers of its enemies, is absolutely necessary for its preservation. Thus we can easily raise plenty of corn and rape-seed, etc., in our fields, because the seeds are in great excess compared with the number of birds which feed on them; nor can the birds, though having a superabundance of food at this one season, increase in number proportionally to the supply of seed, as their numbers are checked during winter; but any one who has tried knows how troublesome it is to get seed from a few wheat or other such plants in a garden: I have in this case lost every single seed. This view of the necessity of a large stock of the same species for its preservation explains, I believe, some singular facts in nature, such as that of very rare plants being sometimes extremely abundant, in the few spots where they do exist; and that of some social plants being social, that is abounding in individuals, even on the extreme verge of their range. For in such cases we may believe that a plant could exist only where the conditions of its life were so favorable that many could exist together, and thus save the species from utter destruction. I should add that the good effects of intercrossing, and the ill effects of close interbreeding, no doubt come into play in many of these cases.

Many cases are on record showing how complex and unexpected are the checks and relations between organic beings which have to struggle together in the same country. I will give only a single instance, which, though a simple one, interested me. In Staffordshire, on the estate of a relation, where I had ample means of investigation, there was a large and extremely barren heath, which had never been touched by the hand of man; but several hundred acres of exactly the same nature had been inclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable, more than is generally seen in passing from one quite different soil to another: not only the proportional numbers of the heath-plants were wholly changed, but twelve species of plants (not counting grasses and carices) flourished in the plantations, which could not be found on the heath. The effect on the insects must have been still greater, for six insectivorous birds were very common in the plantations, which were not to be seen on the heath; and the heath was frequented by two or three distinct insectivorous birds. Here we see how potent has been the effect of the introduction of a single tree, nothing whatever else having been done, with the exception of the land having been inclosed, so that cattle could not enter. But how important an element inclosure is I plainly saw near Farnham, in Surrey. Here there are extensive heaths, with a few clumps of old Scotch firs on the distant hilltops: within the last ten years large spaces have been inclosed, and self-sown firs are now springing up in multitudes, so close together that all can not live. When I ascertained that these young trees had not been sown or planted, I was so much surprised at their numbers that I went to several points of view, whence I could examine hundreds of acres of the uninclosed heath, and literally I could not see a single Scotch fir except the old planted clumps. But on looking closely between the stems of the heath, I found a multitude of seedlings and little trees which had been perpetually browsed down by the cattle. In one square yard, at a point some hundred yards distant from one of the old clumps, I counted thirty-two little trees; and one of them, with twenty-six rings of growth, had, during many years, tried to raise its head above the stems of the heath, and had failed. No wonder that, as soon as the land was inclosed, it became thickly clothed with vigorously growing young firs. Yet the heath was so extremely barren and so extensive that no one would ever have imagined that cattle would have so closely and effectually searched it for food.

Here we see that cattle absolutely determine the existence of the Scotch fir; but in several parts of the world insects determine the existence of cattle. Perhaps Paraguay offers the most curious instance of this; for here neither cattle nor horses nor dogs have ever run wild, though they swarm southward and northward in a feral state; and Azara and Rengger have shown that this is caused by the greater number in Paraguay of a certain fly, which lays its eggs in the navels of these animals when first born. The increase of these flies, numerous as they are, must be habitually checked by some means, probably by other parasitic insects. Hence, if certain insectivorous birds were to decrease in Paraguay, the parasitic insects would probably increase; and this would lessen the number of the navel-frequenting flies—then cattle and horses would become feral, and this would certainly greatly alter (as indeed I have observed in parts of South America) the vegetation: this again would largely affect the insects; and this, as we have just seen in Staffordshire, the insectivorous birds, and so onward in ever-increasing circles of complexity. Not that under nature the relations will ever be as simple as this. Battle within battle must be continually recurring with varying success; and yet in the long run the forces are so nicely balanced that the face of nature remains for long periods of time uniform, though assuredly the merest trifle would give the victory to one organic being over another. Nevertheless, so profound is our ignorance, and so high our presumption, that we marvel when we hear of the extinction of an organic being; and as we do not see the cause, we invoke cataclysms to desolate the world, or invent laws on the duration of the forms of life!

I am tempted to give one more instance showing how plants and animals, remote in the scale of nature, are bound together by a web of complex relations. I shall hereafter have occasion to show that the exotic Lobelia fulgens is never visited in my garden by insects, and consequently, from its peculiar structure, never sets a seed. Nearly all our orchidaceous plants absolutely require the visits of insects to remove their pollen-masses and thus to fertilize them. I find from experiments that humblebees are almost indispensable to the fertilization of the heart's-ease (Violo tricolor), for other bees do not visit this flower. I have also found that the visits of bees are necessary for the fertilization of some kinds of clover; for instance, 20 heads of Dutch clover (Trifolium repens) yielded 2,290 seeds, but 20 other heads protected from bees produced not one. Again, 100 heads of red clover (T. pratense) produced 2,700 seeds, but the same number of protected heads produced not a single seed. Humblebees alone visit red clover, as other bees can not reach the nectar. It has been suggested that moths may fertilize the clovers; but I doubt whether they could do so in the case of the red clover, from their weight not being sufficient to depress the wing petals. Hence we may infer as highly probable that, if the whole genus of humblebees became extinct or very rare in England, the heart's-ease and red clover would become very rare, or wholly disappear. The number of humblebees in any district depends in a great measure upon the number of field-mice, which destroy their combs and nests; and Colonel Newman, who has long attended to the habits of humblebees, believes that "more than two-thirds of them are thus destroyed all over England." Now the number of mice is largely dependent, as every one knows, on the number of cats; and Colonel Newman says, "Near villages and small towns I have found the nests of humblebees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice." Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district!

The dependency of one organic being on another, as of a parasite on its prey, lies generally between beings remote in the scale of nature. This is likewise sometimes the case with those which may be strictly said to struggle with each other for existence, as in the case of locusts and grassfeeding quadrupeds. But the struggle will almost invariably be most severe between the individuals of the same species, for they frequent the same districts, require the same food, and are exposed to the same dangers. In the case of varieties of the same species, the struggle will generally be almost equally severe, and we sometimes see the contest soon decided: for instance, if several varieties of wheat be sown together, and the mixed seed be resown, some of the varieties which best suit the soil or climate, or are naturally the most fertile, will beat the others and so yield more seed, and will consequently in a few years supplant the other varieties. To keep up a mixed stock of even such extremely close varieties as the variously colored sweet peas, they must be each year harvested separately, and the seed then mixed in due proportion, otherwise the weaker kinds will steadily decrease in number and disappear. So again with the varieties of sheep; it has been asserted that certain mountain varieties will starve out other mountain varieties, so that they can not be kept together. The same result has followed from keeping together different varieties of the medicinal leech. It may even be doubted whether the varieties of any of our domestic plants or animals have so exactly the same strength, habits, and constitution, that the original proportions of a mixed stock (crossing being prevented) could be kept up for half a dozen generations, if they were allowed to struggle together, in the same manner as beings in a state of nature, and if the seed or young were not annually preserved in due proportion.

As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure, the struggle will generally be more severe between them, if they come into competition with each other, than between the species of distinct genera. We see this in the extension over parts of the United States of one species of swallow having caused the decrease of another species. The increase of the missel-thrush in parts of Scotland has caused the decrease of the song-thrush. How frequently we hear of one species of rat taking the place of another species under the most different climates! In Russia the small Asiatic cockroach has everywhere driven before it its great congener. In Australia the imported hive-bee is rapidly exterminating the small, stingless native bee. One species of charlock has been known to supplant another species; and so in other cases.

A corollary of the highest importance may be deduced from the foregoing remarks; namely, that the structure of every organic being is related, in the most essential yet often hidden manner, to that of all the other organic beings, with which it comes into competition for food or residence, or from which it has to escape, or on which it preys. This is obvious in the structure of the teeth and talons of the tiger; and in that of the legs and claws of the parasite which clings to the hair on the tiger's body. But in the beautifully plumed seed of the dandelion, and in the flattened and fringed legs of the water-beetle, the relation seems at first confined to the elements of air and water. Yet the advantage of plumed seeds no doubt stands in the closest relation to the land being already thickly clothed with other plants; so that the seeds may be widely distributed and fall on unoccupied ground. In the water-beetle, the structure of its legs, so well adapted for diving, allows it to compete with other aquatic insects, to hunt for its own prey, and to escape serving as prey to other animals.

All that we can do is to keep steadily in mind that each organic being is striving to increase in a geometrical ratio; that each at some period of its life, during some season of the year, during each generation, or at intervals, has to struggle for life and to suffer great destruction. When we reflect on this struggle, we may console ourselves with the full belief that the war of nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous. the healthy, and the happy survive and multiply.

NATURAL SELECTION
—CHARLES DARWIN

HOW will the struggle for existence, briefly discussed in the last chapter, act in regard to variation? Can the principle of selection, which we have seen is so potent in the hands of man, apply under nature? I think we shall see that it can act most efficiently. Let the endless number of slight variations and individual differences occurring in our domestic productions, and, in a lesser degree, in those under nature, be borne in mind; as well as the strength of the hereditary tendency. Under domestication, it may be truly said that the whole organization becomes in some degree plastic. But the variability, which we almost universally meet with in our domestic productions, is not directly produced, as Hooker and Asa Gray have well remarked, by man; he can neither originate varieties, nor prevent their occurrence; he can only preserve and accumulate such as do occur. Unintentionally he exposes organic beings to new and changing conditions of life, and variability ensues; but similar changes of conditions might and do occur under nature. Let it also be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life; and consequently what infinitely varied diversities of structure might be of use to each being under changing conditions of life. Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred, that other variations useful in some way to each being in the great and complex battle of life, should occur in the course of many successive generations? If such do occur, can we doubt (remembering that many more individuals are born than can possibly survive) that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favorable individual differences and variations, and the destruction of those which are injurious, I have called Natural Selection, or the Survival of the Fittest.

We shall best understand the probable course of natural selection by taking the case of a country undergoing some slight physical change, for instance, of climate. The proportional numbers of its inhabitants will almost immediately undergo a change, and some species will probably become extinct. We may conclude, from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of the inhabitants, independently of the change of climate itself, would seriously affect the others. If the country were open on its borders, new forms would certainly immigrate, and this would likewise seriously disturb the relations of some of the former inhabitants. Let it be remembered how powerful the influence of a single introduced tree or mammal has been shown to be. But in the case of an island, or of a country partly surrounded by barriers, into which new and better adapted forms could not freely enter, we should then have places in the economy of nature which would assuredly be better filled up, if some of the original inhabitants were in some manner modified; for, had the area been open to immigration, these same places would have been seized on by intruders. In such cases, slight modifications, which in any way favored the individuals of any species, by better adapting them to their altered conditions, would tend to be preserved; and natural selection would have free scope for the work of improvement.

We have good reason to believe that changes in the conditions of life give a tendency to increased variability; and in the foregoing cases the conditions have changed, and this would manifestly be favorable to natural selection, by affording a better chance of the occurrence of profitable variations. Unless such occur, natural selection can do nothing. Under the term of "variations," it must never be forgotten that mere individual differences are included. As man can produce a great result with his domestic animals and plants by adding up in any given direction individual differences, so could natural selection, but far more easily from having incomparably longer time for action. Nor do I believe that any great physical change, as of climate, or any unusual degree of isolation to check immigration, is necessary in order that new and unoccupied places should be left for natural selection to fill up by improving some of the varying inhabitants. For as all the inhabitants of each country are struggling together with nicely balanced forces, extremely slight modifications in the structure or habits of one species would often give it an advantage over others; and still further modifications of the same kind would often still further increase the advantage, as long as the species continued under the same conditions of life and profited by similar means of subsistence and defence. No country can be named in which all the native inhabitants are now so perfectly adapted to each other and to the physical conditions under which they live, that none of them could be still better adapted or improved; for in all countries the natives have been so far conquered by naturalized productions that they have allowed some foreigners to take firm possession of the land. And as foreigners have thus in every country beaten some of the natives, we may safely conclude that the natives might have been modified with advantage, so as to have better resisted the intruders.

As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature, if I may be allowed to personify the natural preservation or survival of the fittest, cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life. Man selects only for his own good: Nature only for that of the being which she tends. Every selected character is fully exercised by her, as is implied by the fact of their selection. Man keeps the natives of many climates in the same country; he seldom exercises each selected character in some peculiar and fitting manner; he feeds a long and a short-beaked pigeon on the same food; he does not exercise a long-backed or long-legged quadruped in any peculiar manner; he exposes sheep with long and short wool to the same climate. He does not allow the most vigorous males to struggle for the females. He does not rigidly destroy all inferior animals, but protects during each varying season, as far as lies in his power, all his productions. He often begins his selection by some half-monstrous form; or at least by some modification prominent enough to catch the eye or to be plainly useful to him. Under Nature, the slightest differences of structure or constitution may well turn the nicely balanced scale in the struggle for life, and so be preserved. How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will be his results, compared with those accumulated by Nature during whole geological periods! Can we wonder, then, that Nature's productions should be far "truer" in character than man's productions; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship?

It may metaphorically be said that natural selection is daily and hourly scrutinizing, throughout the world, the slightest variations; rejecting those that are bad, preserving and adding up all that are good; silently and insensibly working, *whenever and wherever opportunity offers,* at the improvement of each organic being in relation to its organic and inorganic conditions of life. We see nothing of these slow changes in progress, until the hand of time has marked the lapse of ages, and then so imperfect is our view into long-past geological ages, that we see only that the forms of life are now different from what they formerly were.

In order that any great amount of modification should be effected in a species, a variety when once formed must again, perhaps after a long interval of time, vary or present individual differences of the same favorable nature as before; and these must be again preserved, and so onward step by step. Seeing that individual differences of the same kind perpetually recur, this can hardly be considered as an unwarrantable assumption. But whether it is true, we can judge only by seeing how far the hypothesis accords with and explains the general phenomena of nature. On the other hand, the ordinary belief that the amount of possible variation is a strictly limited quantity is likewise a simple assumption.

Although natural selection can act only through and for the good of each being, yet characters and structures, which we are apt to consider as of very trifling importance, may thus be acted on. When we see leaf-eating insects green, and bark-feeders mottled-gray; the Alpine ptarmigan white in winter, the red grouse the color of heather, we must believe that these tints are of service to these birds and insects in preserving them from danger. Grouse, if not destroyed at some period of their lives, would increase in countless numbers; they are known to suffer largely from birds of prey; and hawks are guided by eyesight to their prey—so much so, that on parts of the Continent persons are warned not to keep white pigeons, as being the most liable to destruction. Hence natural selection might be effective in giving the proper color to each kind of grouse, and in keeping that color, when once acquired, true and constant. Nor ought we to think that the occasional destruction of an animal of any particular color would produce little effect: we should remember how essential it is in a flock of white sheep to destroy a lamb with the faintest trace of black. In plants, the down on the fruit and the color of the flesh are considered by botanists as characters of the most trifling importance: yet we hear from an excellent horticulturist, Downing, that in the United States smooth-skinned fruits suffer far more from a beetle, a Curculio, than those with down; that purple plums suffer far more from a certain disease than yellow plums; whereas another disease attacks yellow-fleshed peaches far more than those with other colored flesh. If, with all the aids of art, these slight differences make a great difference in cultivating the several varieties, assuredly, in a state of nature, where the trees would have to struggle with other trees and with a host of enemies, such differences would effectually settle which variety, whether a smooth or downy, a yellow or purple fleshed fruit, should succeed.

In looking at many small points of difference between species, which, as far as our ignorance permits us to judge, seem quite unimportant, we must not forget that climate, food, etc., have no doubt produced some direct effect. It is also necessary to bear in mind that, owing to the law of correlation, when one part varies, and the variations are accumulated through natural selection, other modifications, often of the most unexpected nature, will ensue.

Natural selection will modify the structure of the young in relation to the parent, and of the parent in relation to the young. In social animals it will adapt the structure of each individual for the benefit of the whole community; if the community profits by the selected change. What natural selection can not do is to modify the structure of one species, without giving it any advantage, for the good of another species; and though statements to this effect may be found in works of natural history, I can not find one case which will bear investigation. A structure used only once in an animal's life, if of high importance to it, might be modified to any extent by natural selection; for instance, the great jaws possessed by certain insects, used exclusively for opening the cocoon —or the hard tip to the beak of unhatched birds, used for breaking the egg. It has been asserted that of the best short-beaked tumbler-pigeons a greater number perish in the egg than are able to get out of it; so that fanciers assist in the act of hatching. Now if nature had to make the beak of a full-grown pigeon short for the bird's own advantage, the process of modification would be very slow and there would be simultaneously the most rigorous selection of all the young birds within the egg, which had the most powerful and hardest beaks, for all with weak beaks would inevitably perish; or, more delicate and more easily broken shells might be selected, the thickness of the shell being known to vary like every other structure.

Inasmuch as peculiarities often appear under domestication in one sex and become hereditarily attached to that sex, so no doubt it will be under nature. Thus it is rendered possible for the two sexes to be modified through natural selection in relation to different habits of life, as is sometimes the case; or for one sex to be modified in relation to the other sex, as commonly occurs. This leads me to say a few words on what I have called Sexual Selection. This form of selection depends, not on a struggle for existence in relation to other organic beings or to external conditions, but on a struggle between the individuals of one sex, generally the males, for the possession of the other sex. The result is not death to the unsuccessful competitor, but few or no offspring. Sexual selection is, therefore, less rigorous than natural selection. Generally, the most vigorous males, those which are best fitted for their places in nature, will leave most progeny. But in many cases, victory depends not so much on general vigor as on having special weapons, confined to the male sex. A hornless stag or spurless cock would have a poor chance of leaving numerous offspring. Sexual selection, by always allowing the victor to breed, might surely give indomitable courage, length to the spur, and strength to the wing to strike in the spurred leg, in nearly the same manner as does the brutal cockfighter by the careful selection of his best cocks. How low in the scale of nature the law of battle descends I know not; male alligators have been described as fighting, bellowing, and whirling round, like Indians in a war-dance, for the possession of the females; male salmon have been observed fighting all day long; male stag-beetles sometimes bear wounds from the huge mandibles of other males; the males of certain hymenopterous insects have been frequently seen by that inimitable observer, M. Fabre, fighting for a particular female who sits by, an apparently unconcerned beholder of the struggle, and then retires with the conqueror. The war is, perhaps, severest between the males of polygamous animals, and these seem oftenest provided with special weapons. The males of carnivorous animals are already well armed; though to them and to others special means of defence may be given through means of sexual selection, as the mane of the lion and the hooked jaw to the male salmon; for the shield may be as important for victory as the sword or spear.

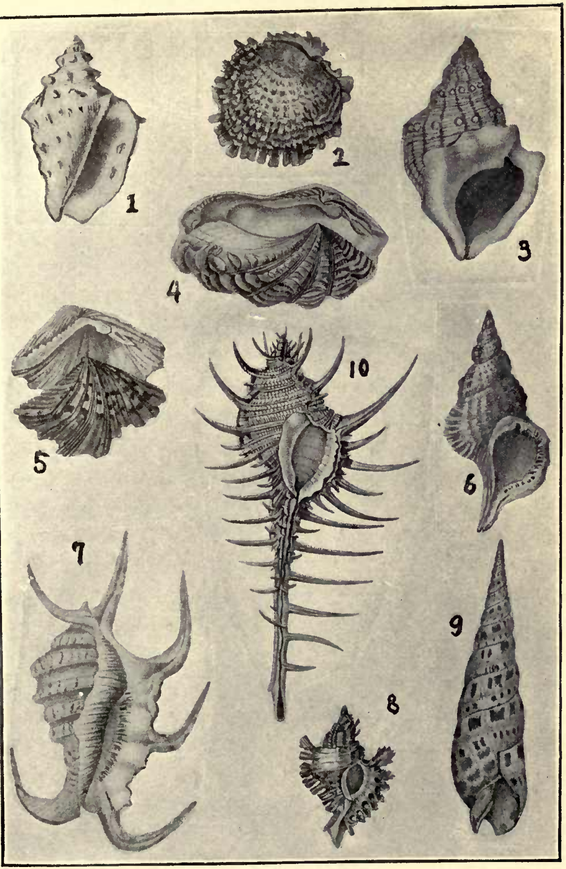
Among birds, the contest is often of a more peaceful character. All those who have attended to the subject believe that there is the severest rivalry between the males of many species to attract, by singing, the females. The rock-thrush of Guiana, birds of paradise, and some others, congregate; and successive males display with the most elaborate care, and show off in the best manner, their gorgeous plumage; they likewise perform strange antics before the females, which, standing by as spectators, at last choose the most attractive partner. Those who have closely attended to birds in confinement well know that they often take individual preferences and dislikes: thus Sir R. Heron has described how a pied peacock was eminently attractive to all his hen birds. I can not here enter on the necessary details; but if man can in a short time give beauty and an elegant carriage to his bantams, according to his standard of beauty, I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their standard of beauty, might produce a marked effect.

Some well-known laws, with respect to the plumage of male and female birds, in comparison with the plumage of the young, can partly be explained through the action of sexual selection on variations occurring at different ages, and transmitted to the males alone or to both sexes at corresponding ages.

Thus it is, as I believe, that when the males and females of any animal have the same general habits of life, but differ in structure, color, or ornament, such differences have been mainly caused by sexual selection: that is, by individual males having had, in successive generations, some slight advantage over other males, in their weapons, means of defence, or charms, which they have transmitted to their male offspring alone. Yet, I would not wish to attribute all sexual differences to this agency: for we see in our domestic animals peculiarities arising and becoming attached to the male sex, which apparently have not been augmented through selection by man. The tuft of hair on the breast of the wild turkey-cock can not be of any use, and it is doubtful whether it can be ornamental in the eyes of the female bird;—indeed, had the tuft appeared under domestication, it would have been called a monstrosity.

In order to make it clear how, as I believe, natural selection acts, I must beg permission to give one or two imaginary illustrations. Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer, for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf was hardest pressed for food. Under such circumstances the swiftest and slimmest wolves would have the best chance of surviving and so be preserved or selected—provided always that they retained strength to master their prey at this or some other period of the year, when they were compelled to prey on other animals. I can see no more reason to doubt that this would be the result than that man should be able to improve the fleetness of his greyhounds by careful and methodical selection, or by that kind of unconscious selection which follows from each man trying to keep the best dogs without any thought of modifying the breed. I may add, that, according to Mr. Pierce, there are two varieties of the wolf inhabiting the Catskill Mountains, in the United States, one with a light greyhound-like form, which pursues deer, and the other more bulky, with shorter legs, which more frequently attacks the shepherd's flocks.

To the effects of intercrossing in eliminating variations of all kinds, I shall have to recur; but it may be here remarked that most animals and plants keep to their proper homes, and do not needlessly wander about; we see this even with migratory birds, which almost always return to the same spot. Consequently each newly formed variety would generally be at first local, as seems to be the common rule with varieties in a state of nature; so that similarly modified individuals would soon exist in a small body together, and would often breed together. If the new variety were successful in its battle for life, it would slowly spread from a central district, competing with and



Beautiful and Curious Shells

1, Strombus; 2, Chama; 3, Struthiolaria; 4, Tridacna; 5, Hippopus; 6, Ranella; 7, Pteroceras; 8, 10, Murex; 9, Terebra

conquering the unchanged individuals on the margins of an ever-increasing circle.

It may be worth while to give another and more complex illustration of the action of natural selection. Certain plants excrete sweet juice, apparently for the sake of eliminating something injurious from the sap: this is effected, for instance, by glands at the base of the stipules in some Leguminosæ, and at the backs of the leaves of the common laurel. This juice, though small in quantity, is greedily sought by insects; but their visits do not in any way benefit the plant. Now, let us suppose that the juice or nectar was excreted from the inside of the flowers of a certain number of plants of any species. Insects in seeking the nectar would get dusted with pollen, and would often transport it from one flower to another. The flowers of two distinct individuals of the same species would thus get crossed; and the act of crossing, as can be fully proved, gives rise to vigorous seedlings, which consequently would have the best chance of flourishing and surviving. The plants which produced flowers with the largest glands or nectaries, excreting most nectar, would oftenest be visited by insects, and would oftenest be crossed; and so in the long run would gain the upper hand and form a local variety. The flowers, also, which had their stamens and pistils placed, in relation to the size and habits of the particular insect which visited them, so as to favor in any degree the transportal of the pollen, would likewise be favored. We might have taken the case of insects visiting flowers for the sake of collecting pollen instead of nectar; and as pollen is formed for the sole purpose of fertilization, its destruction appears to be a simple loss to the plant; yet if a little pollen were carried, at first occasionally and then habitually, by the pollen-devouring insects from flower to flower, and a cross thus effected, although nine-tenths of the pollen were destroyed it might still be a great gain to the plant to be thus robbed; and the individuals which produced more and more pollen, and had larger anthers, would be selected.

When our plant, by the above process long continued, had been rendered highly attractive to insects, they would, unintentionally on their part, regularly carry pollen from flower to flower; and that they do this effectually, I could easily show by many striking facts.

Let us now turn to the nectar-feeding insects; we may suppose the plant, of which we have been slowly increasing the nectar by continued selection, to be a common plant; and that certain insects depended in main part on its nectar for food. I could give many facts showing how anxious bees are to save time: for instance, their habit of cutting holes and sucking the nectar at the bases of certain flowers, which with a very little more trouble they can enter by the mouth. Bearing such facts in mind, it may be believed that under certain circumstances individual differences in the curvature or length of the proboscis, etc., too slight to be appreciated by us, might profit a bee or other insect, so that certain individuals would be able to obtain their food more quickly than others; and thus the communities to which they belonged would flourish and throw off many swarms inheriting the same peculiarities. The tubes of the corolla of the common red and incarnate clovers (Trifolium pratense and incarnatum) do not on a hasty glance appear to differ in length; yet the hive-bee can easily suck the nectar out of the incarnate clover, but not out of the common red clover, which is visited by humblebees alone; so that whole fields of the red clover offer in vain an abundant supply of precious nectar to the hive-bee. That this nectar is much liked by the hive-bee is certain; for I have repeatedly seen, but only in the autumn, many hive-bees sucking the flowers through holes bitten in the base of the tube by humblebees. The difference in the length of the corolla in the two kinds of clover, which determines the visits of the hive-bee, must be very trifling; for I have been assured that when red clover has been mown, the flowers of the second crop are somewhat smaller, and that these are visited by many hive-bees. I do not know whether this statement is accurate; nor whether another published statement can be trusted, namely, that the Ligurian bee, which is generally considered a mere variety of the common hive-bee, and which freely crosses with it, is able to reach and suck the nectar of the red clover. Thus, in a country where this kind of clover abounded, it might be a great advantage to the hive-bee to have a slightly longer or differently constructed proboscis. On the other hand, as the fertility of this clover absolutely depends on bees visiting the flowers, if humblebees were to become rare in any country, it might be a great advantage to the plant to have a shorter or more deeply divided corolla, so that the hive-bees should be enabled to suck its flowers. Thus I can understand how a flower and a bee might slowly become, either simultaneously or one after the other, modified and adapted to each other in the most perfect manner, by the continued preservation of all the individuals which presented slight deviations of structure mutually favorable to each other.

I must here introduce a short digression. In the case of animals and plants with separated sexes, it is of course obvious that two individuals must always (with the exception of the curious and not well understood cases of parthenogenesis) unite for each birth; but in the case of hermaphrodites this is far from obvious. Nevertheless there is reason to believe that with all hermaphrodites two individuals, either occasionally or habitually, concur for the reproduction of their kind. This view was long ago doubtfully suggested by Sprengel, Knight, and Kölreuter. We shall presently see its importance; but I must here treat the subject with extreme brevity, though I have the materials prepared for an ample discussion. All vertebrate animals, all insects, and some other large groups of animals, pair for each birth. Modern research has much diminished the number of supposed hermaphrodites; and of real hermaphrodites a large number pair; that is, two individuals regularly unite for reproduction, which is all that concerns us. But still there are many hermaphrodite animals which certainly do not habitually pair, and a vast majority of plants are hermaphrodites. What reason, it may be asked, is there for supposing in these cases that two individuals ever concur in reproduction? As it is impossible here to enter on details, I must trust to some general considerations alone.

In the first place, I have collected so large a body of facts, and made so many experiments, showing, in accordance with the almost universal belief of breeders, that with animals and plants a cross between different varieties, or between individuals of the same variety but of another strain, gives vigor and fertility to the offspring; and, on the other hand, that *close* interbreeding diminishes vigor and fertility; that these facts alone incline me to believe that it is a general law of nature that no organic being fertilizes itself for a perpetuity of generations; but that a cross with another individual is occasionally—perhaps at long intervals of time—indispensable.

Turning for a brief space to animals; various terrestrial species are hermaphrodites, such as the land-mollusca and earthworms; but these all pair. As yet I have not found a single terrestrial animal which can fertilize itself. This remarkable fact, which offers so strong a contrast with terrestrial plants, is intelligible on the view of an occasional cross being indispensable; for owing to the nature of the fertilizing element there are no means, analogous to the action of insects and of the wind with plants, by which an occasional cross could be effected with terrestrial animals without the concurrence of two individuals. Of aquatic animals, there are many self-fertilizing hermaphrodites; but here the currents of water offer an obvious means for an occasional cross.

As in the case of flowers, I have as yet failed, after consultation with one of the highest authorities, namely, Professor Huxley, to discover a single hermaphrodite animal with the organs of reproduction so perfectly inclosed that access from without, and the occasional influence of a distinct individual, can be shown to be physically impossible. Cirripeds long appeared to me to present, under this point of view, a case of great difficulty; but I have been enabled, by a fortunate chance, to prove that two individuals, though both are self-fertilizing hermaphrodites, do sometimes cross.

It must have struck most naturalists as a strange anomaly that, both with animals and plants, some species of the same family and even of the same genus, though agreeing closely with each other in their whole organization, are hermaphrodites, and some unisexual. But if, in fact, all hermaphrodites do occasionally intercross, the difference between them and unisexual species is, as far as function is concerned, very small.

From these several considerations and from the many special facts which I have collected, but which I am unable here to give, it appears that with animals and plants an occasional intercross between distinct individuals is a very general, if not universal, law of nature.

To sum up, as far as the extreme intricacy of the subject permits, the circumstances favorable and unfavorable for the production of new species through natural selection. I conclude that for terrestrial productions a large continental area, which has undergone many oscillations of level, will have been the most favorable for the production of any new forms of life, fitted to endure for a long time and to spread widely. While the area existed as a continent, the inhabitants will have been numerous in individuals and kinds, and will have been subjected to severe competition. When converted by subsidence into large separate islands, there will still have existed many individuals of the same species on each island: intercrossing on the confines of the range of each new species will have been checked: after physical changes of any kind, immigration will have been prevented, so that new places in the polity of each island will have had to be filled up by the modification of the old inhabitants; and time will have been allowed for the varieties in each to become well modified and perfected. When, by renewed elevation, the islands were reconverted into a continental area, there will again have been very severe competition: the most favored or improved varieties will have been enabled to spread: there will have been much extinction of the less improved forms, and the relative proportional numbers of the various inhabitants of the reunited continent will again have been changed; and again there will have been a fair field for natural selection to improve still further the inhabitants, and thus to produce new species.

That natural selection generally acts with extreme slowness I fully admit. It can act only when there are places in the natural polity of a district which can be better occupied by the modification of some of its existing inhabitants. The occurrence of such places will often depend on physical changes, which generally take place very slowly, and on the immigration of better adapted forms being prevented. As some few of the old inhabitants become modified, the mutual relations of others will often be disturbed; and this will create new places, ready to be filled up by better adapted forms; but all this will take place very slowly. Although all the individuals of the same species differ in some slight degree from each other, it would often be long before differences of the right nature in various parts of the organization might occur. The result would often be greatly retarded by free intercrossing. Many will exclaim that these several causes are amply sufficient to neutralize the power of natural selection. I do not believe so. But I do believe that natural selection will generally act very slowly, only at long intervals of time, and only on a few of the inhabitants of the same region. I further believe that these slow, intermittent results accord well with what geology tells us of the rate and manner at which the inhabitants of the world have changed.

Slow though the process of selection may be, if feeble man can do much by artificial selection, I can see no limit to the amount of change, to the beauty and complexity of the coadaptations between all organic beings, one with another and with their physical conditions of life, which may have been effected in the long course of time through nature's power of selection, that is, by the survival of the fittest.

Natural selection acts solely through the preservation of variations in some way advantageous, which consequently endure. Owing to the high geometrical rate of increase of all organic beings, each area is already fully stocked with inhabitants; and it follows from this, that as the favored forms increase in number, so, generally, will the less favored decrease and become rare. Rarity, as geology tells us, is the precursor to extinction. We can see that any form which is represented by few individuals will run a good chance of utter extinction, during great fluctuations in the nature of the seasons, or from a temporary increase in the number of its enemies. But we may go further than this; for, as new forms are produced, unless we admit that specific forms can go on indefinitely increasing in number, many old forms must become extinct. That the number of specific forms has not indefinitely increased, geology plainly tells us; and we shall attempt to show why it is that the number of species throughout the world has not become immeasurably great.

We have seen that the species which are most numerous in individuals have the best chance of producing favorable variations within any given period. It is the common and diffused or dominant species which offer the greatest number of recorded varieties. Hence, rare species will be less quickly modified or improved within any given period; they will consequently be beaten in the race for life by the modified and improved descendants of the commoner species.

From these several considerations I think it inevitably follows that as new species in the course of time are formed through natural selection, others will become rarer and rarer, and finally extinct. The forms which stand in closest competition with those undergoing modification and improvement will naturally suffer most. And we have seen in the chapter on the Struggle for Existence that it is the most closely allied forms—varieties of the same species, and species of the same genus or of related genera—which, from having nearly the same structure, constitution, and habits, generally come into the severest competition with each other; consequently, each new variety or species, during the progress of its formation, will generally press hardest on its nearest kindred, and tend to exterminate them. We see the same process of extermination among our domesticated productions, through the selection of improved forms by man. Many curious instances could be given showing how quickly new breeds of cattle, sheep, and other animals, and varieties of flowers, take the place of older and inferior kinds. In Yorkshire, it is historically known that the ancient black cattle were displaced by the long-horns, and that these "were swept away by the short-horns" (I quote the words of an agricultural writer) "as if by some murderous pestilence."

Divergence of character is of high importance, and explains, as I believe, several important facts. In the first place, varieties, even strongly marked ones, though having somewhat of the character of species—as is shown by the hopeless doubts in many cases of how to rank them—yet certainly differ far less from each other than do good and distinct species. Nevertheless, according to my view, varieties are species in the process of formation, or are, as I have called them, incipient species. How, then, does the lesser difference between varieties become augmented into the greater difference between species? That this does habitually happen, we must infer from most of the innumerable species throughout nature presenting well-marked differences, whereas varieties, the supposed prototypes and parents of future well-marked species, present slight and ill-defined differences. Mere chance, as we may call it, might cause one variety to differ in some character from its parents, and the offspring of this variety again to differ from its parent in the very same character and in a greater degree; but this alone would never account for so habitual and large a degree of difference as that between the species of the same genus.

As has always been my practice, I have sought light on this head from our domestic productions. We shall here find something analogous. It will be admitted that the production of races so different as short-horn and Hereford cattle, race and cart-horses, the several breeds of pigeons, etc., could never have been effected by the mere chance accumulation of similar variations during many successive generations. In practice, a fancier is, for instance, struck by a pigeon having a slightly shorter beak; another fancier is struck by a pigeon having a rather longer beak; and on the acknowledged principle that "fanciers do not and will not admire a medium standard, but like extremes," they both go on (as has actually occurred with the sub-breeds of the tumbler-pigeon) choosing and breeding from birds with longer and longer beaks, or with shorter and shorter beaks. Again, we may suppose that at an early period of history, the men of one nation or district required swifter horses, while those of another required stronger and bulkier horses. The early differences would be very slight, but, in the course of time, from the continued selection of swifter horses in the one case, and of stronger ones in the other, the differences would become greater, and would be noted as forming two sub-breeds. Ultimately, after the lapse of centuries, these sub-breeds would become converted into two well-established and distinct breeds. As the differences became greater, the inferior animals with intermediate characters, being neither very swift nor very strong, would not have been used for breeding, and will thus have tended to disappear. Here, then, we see in man's productions the action of what may be called the principle of divergence, causing differences, at first barely appreciable, steadily to increase, and the breeds to diverge in character, both from each other and from their common parent.

But how, it may be asked, can any analogous principle apply in nature? I believe it can and does apply most efficiently (though it was a long time before I saw how), from the simple circumstance that the more diversified the descendants from any one species become in structure, constitution, and habits, by so much will they be better enabled to seize on many and widely diversified places in the polity of nature, and so be enabled to increase in numbers.

We can clearly discern this in the case of animals with simple habits. Take the case of a carnivorous quadruped, of which the number that can be supported in any country has long ago arrived at its full average. If its natural power of increase be allowed to act, it can succeed in increasing (the country not undergoing any change in conditions) only by its varying descendants seizing on places at present occupied by other animals: some of them, for instance, being enabled to feed on new kinds of prey, either dead or alive; some inhabiting new stations, climbing trees, frequenting water, and some perhaps becoming less carnivorous. The more diversified in habits and structure the descendants of our carnivorous animals become, the more places they will be enabled to occupy. What applies to one animal will apply throughout all time to all animals—that is, if they vary—for otherwise natural selection can effect nothing.

By considering the nature of the plants or animals which have in any country struggled successfully with the indigenes, and have there become naturalized, we may gain some crude idea in what manner some of the natives would have to be modified in order to gain an advantage over their compatriots; and we may at least infer that diversification of structure, amounting to new generic differences, would be profitable to them.

The advantage of diversification of structure in the inhabitants of the same region is, in fact, the same as that of the physiological division of labor in the organs of the same individual body—a subject so well elucidated by Milne Edwards. No physiologist doubts that a stomach adapted to digest vegetable matter alone, or flesh alone, draws most nutriment from these substances. So in the general economy of any land, the more widely and perfectly the animals and plants are diversified for different habits of life, so will a greater number of individuals be capable of there supporting themselves. A set of animals, with their organization but little diversified, could hardly compete with a set more perfectly diversified in structure. It may be doubted, for instance, whether the Australian marsupials, which are divided into groups differing but little from each other, and feebly representing, as Mr. Waterhouse and others have remarked, our carnivorous, ruminant, and rodent mammals, could successfully compete with these well-developed orders. In the Australian mammals, we see the process of diversification in an early and incomplete stage of development.

If under changing conditions of life organic beings present individual differences in almost every part of their structure, and this can not be disputed; if there be, owing to their geometrical rate of increase, a severe struggle for life at some age, season, or year, and this certainly can not be disputed; then, considering the infinite complexity of the relations of all organic beings to each other and to their conditions of life, causing an infinite diversity in structure, constitution, and habits, to be advantageous to them, it would be a most extraordinary fact if no variations had ever occurred useful to each being's own welfare, in the same manner as so many variations have occurred useful to man. But if variations useful to any organic being ever do occur, assuredly individuals thus characterized will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance, these will tend to produce offspring similarly characterized. This principle of preservation, or the survival of the fittest, I have called Natural Selection. It leads to the improvement of each creature in relation to its organic and inorganic conditions of life; and consequently, in most cases, to what must be regarded as an advance in organization. Nevertheless, low and simple forms will long endure if well fitted for their simple conditions of life.

Natural selection, on the principle of qualities being inherited at corresponding ages, can modify the egg, seed, or young, as easily as the adult. Among many animals, sexual selection will have given its aid to ordinary selection, by assuring to the most vigorous and best adapted males the greatest number of offspring. Sexual selection will also give characters useful to the males alone, in their struggles or rivalry with other males; and these characters will be transmitted to one sex or to both sexes, according to the form of inheritance which prevails.

Whether natural selection has really thus acted, in adapting the various forms of life to their several conditions and stations, must be judged by the general tenor and balance of evidence. But we have already seen how it entails extinction; and how largely extinction has acted in the world's history, geology plainly declares. Natural selection, also, leads to divergence of character; for the more organic beings diverge in structure, habits, and constitution, by so much the more can a large number be supported on the area—of which we see proof by looking to the inhabitants of any small spot, and to the productions naturalized in foreign lands. Therefore, during the modification of the descendants of any one species, and during the incessant struggle of all species to increase in numbers, the more diversified the descendants become, the better will be their chance of success in the battle for life. Thus the small differences distinguishing varieties of the same species steadily tend to increase, till they equal the greater differences between species of the same genus, or even of distinct genera.

We have seen that it is the common, the widely diffused and widely ranging species, belonging to the larger genera within each class, which vary most; and these tend to transmit to their modified offspring that superiority which now makes them dominant in their own countries. Natural selection, as has just been remarked, leads to divergence of character and to much extinction of the less improved and intermediate forms of life. On these principles, the nature of the affinities, and the generally well-defined distinctions between the innumerable organic beings in each class throughout the world, may be explained. It is a truly wonderful fact—the wonder of which we are apt to overlook from familiarity—that all animals and all plants throughout all time and space should be related to each other in groups, subordinate to groups, in the manner which we everywhere behold; namely, varieties of the same species most closely related, species of the same genus less closely and unequally related, forming sections and sub-genera, species of distinct genera much less closely related, and genera related in different degrees, forming sub-families, families, orders, sub-classes and classes. The several subordinate groups in any class can not be ranked in a single file, but seem clustered round points, and these round other points, and so on in almost endless cycles. If species had been independently created, no explanation would have been possible of this kind of classification; but it is explained through inheritance and the complex action of natural selection, entailing extinction and divergence of character.

The affinities of all the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. The green and budding twigs may represent existing species; and those produced during former years may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have at all times overmastered other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was young, budding twigs; and this connection of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. Of the many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear the other branches; so with the species which lived during long-past geological periods, very few have left living and modified descendants. From the first growth of the tree, many a limb and branch has decayed and dropped off; and these fallen branches of various sizes may represent those whole orders, families, and genera which have now no living representatives, and which are known to us only in a fossil state. As we here and there see a thin straggling branch springing from a fork low down in a tree, and which by some chance has been favored and is still alive on its summit, so we occasionally see an animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches of life, and which has apparently been saved from fatal competition by having inhabited a protected station. As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever-branching and beautiful ramifications.

MAMMALIA.—Baron Cuvier

THE mammalia are placed at the head of the animal kingdom not only because it is the class to which man himself belongs, but also because it is that which enjoys the most numerous faculties, the most delicate sensations, the most varied powers of motion, and in which all the different qualities seem combined in order to produce a most perfect degree of intelligence, the one most fertile in resources, most susceptible of perfection, and least the slave of instinct.

As their quantity of respiration is moderate, they are designed in general for walking on the earth, but with vigorous and continued steps. The forms of the articulations of their skeleton are, consequently, strictly defined, which determines all their motions with the most rigorous precision.

Some of them, however, by means of limbs considerably elongated and extended membranes, raise themselves in the air; others have them so shortened that they can move with facility in water only, though this does not deprive them of the general character of the class.

The upper jaw in all of these animals is fixed to the cranium; the lower jaw is formed of two pieces only, articulated by a projecting condyle to a fixed temporal bone; the neck consists of seven vertebræ; one single species excepted, which has nine; the anterior ribs are attached before, by cartilage to a sternum consisting of several vertical pieces; their anterior extremity commences in a shoulder-blade, that is not articulated, but simply suspended in the flesh, often resting on the sternum by means of an intermediate bone, called a clavicle. This extremity is continued by an arm, a forearm, and a hand, the latter being composed of two ranges of small bones called the carpus, of another range called the metacarpus, and of the fingers, each of which consists of two or three bones, termed phalanges.

With the exception of the cetacea, the first part of the posterior extremity in all animals of this class is fixed to the spine, forming a girdle or pelvis, which, in youth, consists of three pairs of bones, the ilium which is attached to the spine, the pubis which forms the anterior part of the girdle, and the ischium, the posterior. At the point of union of these three bones is situated the cavity with which the thigh is articulated, to which, in its turn, is attached the leg, formed of two bones, the tibia and fibula; this extremity is terminated by parts similar to those of the hand, *i. e.,* by a tarsus, metatarsus, and toes.

The head of the mammalia is always articulated by two condyles, with the atlas, the first vertebra of the neck.

The brain is always composed of two hemispheres, united by a medullary layer, called the corpus callosum, containing the ventricles, and enveloping four pairs of tubercles, named the corpora striata, or striated bodies, the thalami nervorum opticorum, or beds of the optic nerves, and the nates and testes. Between the optic beds is a third ventricle, which communicates with a fourth under the cerebellum, the crura of which always form a transverse prominence under the medulla oblongata, called the pons Varolii, or bridge of Varolius.

The eye, invariably lodged in its orbit, is protected by two lids and a vestige of a third, and has its crystalline fixed by the ciliary processes—its sclerotic is simply cellular.

The ear always contains a cavity called the tympanum, or drum, which communicates with the mouth by the Eustachian tube; the cavity itself is closed externally by a membrane called the membrana tympani, and contains a chain of four little bones, named the incus or anvil, malleus or hammer, the os orbiculare or circular bone, and the stapes or stirrup; a vestibule, on the entrance of which rests the stapes, and which communicates with three semicircular canals; and finally a cochlea, which terminates by one canal in the vestibule and by the other in the tympanum.

Their cranium is subdivided into three portions; the anterior is formed by the two frontal and ethmoidal bones, the middle by the two ossa parietalia and the os ethmoides, and the posterior by the os occipitis. Between the ossa parietalia, the sphenoidalis, and the os occipitis are interposed the two temporal bones, part of which belong properly to the face.

Their face consists of two maxillary bones, between which pass the nostrils; the two intermaxillaries are situated before and the two ossa palati behind them; between these descends the vomer, a bony process of the os ethmoides; at the entrance of the nasal canal are placed the ossa nasi; to its external parietes adhere the inferior turbinated bones, the superior ones which occupy its upper and posterior portion belonging to the os ethmoides. The jugal or cheek bone unites the maxillary to the temporal bone on each side, and frequently to the os frontis; finally the os unguis and pars plana of the ethmoid bone occupy the internal angle of the orbit, and sometimes a part of the cheek. In the embryo state these bones also are much more subdivided.

Their tongue is always fleshy, connected with a bone called the hyoides, which is composed of several pieces, and suspended from the cranium by ligaments.

Their lungs, two in number, divided into lobes and composed of an infinite number of cells, are always inclosed, without any adhesion, in a cavity formed by the ribs and diaphragm and lined by the pleura; the organ of voice is always at the upper extremity of the trachea; a fleshy curtain, called the velum palati, establishes a direct communication between their larynx and nasal canal.

Their residence on the surface of the earth rendering them less exposed to the alternations of cold and heat, their tegument, the hair, is but moderately thick, and in such as inhabit warm climates even that is rare.

The Cetacea, which live exclusively in water, are the only ones that are altogether deprived of it.

The young are nourished for some time after birth by a fluid (milk) peculiar to animals of this class, which is produced by the mammæ at the time of parturition, and continues to be so long as is necessary. It is from the mammæ that this class derives its name, and being a character peculiar to it, they distinguish it better than any other that is external.

The variable characters which form essential differences among the mammalia are taken from the organs of touch, on which depends their degree of ability or address, and from the organs of manducation, which determine the nature of their ailment, and are all closely connected, not only with everything relative to the function of digestion, but also with a multitude of other differences relating to their intelligence.

The degree of perfection of the organs of touch is estimated by the number and the pliability of the fingers, and from the greater or less extent to which their extremities are enveloped by the nail or the hoof.

A hoof which completely envelops the end of the toe blunts its sensibility, and renders the foot incapable of seizing.

The opposite extreme is when a nail, formed of one single lamina, covers only one of the faces of the extremity of the finger, leaving the other possessed of all its delicacy.

The nature of the food is known by the grinders, to the form of which the articulation of the jaws universally corresponds.

To cut flesh, grinders are required as trenchant as a saw and jaws fitted like scissors, having no other motion than a vertical one.

For bruising roots or grains flat-crowned grinders are necessary, and jaws that have a lateral motion;

in order that inequalities may always exist on the crown of these teeth, it is also requisite that their substance be composed of parts of unequal hardness, so that one may wear away faster than others.

Hoofed animals are necessarily herbivorous, and have flat-crowned grinders, inasmuch as their feet preclude the possibility of their seizing a living prey.

Animals with unguiculated fingers were susceptible of more variety; their food is of all kinds, and independently of the form of their grinders, they differ greatly from each other in the pliability and delicacy of their fingers. There is one character with respect to this which has immense influence on their dexterity and greatly multiplies its powers; it is the faculty of opposing the thumb to the finger for the purpose of seizing minute objects, constituting what is properly called a hand, a faculty which is carried to its highest perfection in man, in whom the whole anterior extremity is free and capable of prehension.

These various combinations which strictly determine the nature of the different mammalia have given rise to the following orders:

Among the unguiculated animals, the first is Man, who, in addition to privileges of other descriptions, possesses hands at the anterior extremities only, the posterior being designed to support him in an erect position.

In the order next to man, that of the Quadrumana, we find hands at the four extremities.

In another order, that of the Carnivora, the thumb is not free, and can not be opposed to the anterior extremities.

Each of these orders has the three sorts of teeth, grinders, canini, and incisors, or cutting teeth.

In the fourth order, that of the Rodentia, the toes differ but little from those of the Carnivora, but there are no canine teeth, and the incisors are placed in front of the mouth, and adapted to a very peculiar sort of manducation.

Then come those animals whose toes are much cramped and deeply sunk in large nails, which are generally curved; they have no incisors, and in some the canines disappear, while others have none of any description. We comprise them all under the title of Edentata.

This distribution of the unguiculated animals would be perfect and form a very regular series were it not that New Holland has lately furnished us with a little collateral one, consisting of animals with pouches, the different genera of which are connected by a general similarity of organization; some of them, however, in the teeth and nature of their diet corresponding to the Carnivora and others to the Rodentia, and a third to the Edentata.

The hoofed animals are less numerous, and have likewise fewer irregularities.

The Ruminantia, by their cloven foot, the absence of true incisors in their upper jaw, and their four stomachs, form an order that is very distinct.

The remaining hoofed animals may all be united in a single order, which I shall call Pachydermata or Jumenta, the elephant excepted, which might constitute a separate one, and which is remotely connected with that of the Rodentia.

In the last place we find those of the mammalia which have no posterior extremities, whose piscatory form and aquatic mode of life would induce us to form them into a particular class, were it not that in everything else their economy is similar to that in which we have them. These are the hot-blooded fishes of the ancients, or the Cetacea, which, uniting to the vigor of the other mammalia the advantage of being sustained by the watery element, present to our wondering sight the most gigantic of animals.

ZOOLOGICAL ZONES

—Sir Richard Owen

ORGANIC life in its animal form is much more developed, and more variously, in the sea than in its vegetable form.

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

Of such provinces of marine life, that much-lamented, far-seeing, and genial philosopher, Edward Forbes, has provisionally defined twenty-five.

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

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

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

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

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

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

The class of animals to which the restrictive laws of geographical distribution might seem least applicable is that of birds: their peculiar power of locomotion, associated in numerous species with migratory habits, might seem to render them independent of every influence, save those of climate and of food, which directly affects the conditions of their existence. Yet the long-winged albatross is never met with north of the equator; nor does the condor soar above other mountains than the Andes. The geographical range of its European representative, the strong-winged lammergeyer, is similarly restricted. The Asiatic Phasianidæ and Pavonidæ are represented by turkeys (Meleagris) in America; by the guinea-fowl (Numida Agelastus, Phasidus) in Africa, and by the Megapodiæ or mound birds in Australia. Several genera of finches are peculiar to the Galapagos Islands; the richly and fantastically ornate birds of paradise are restricted to New Guinea and some neighboring isles. Mr. Sclater, who has contributed the latest summary of facts on the distribution of birds, reckons seventeen families as peculiar to America and sixteen families as peculiar to Europe, Asia, and Africa. Some species have a singularly restricted locality, as the red-grouse (Tetrao scoticus) to the British Isles; the owl-parrot (Nestor productus) to Philip Island, a small spot near New Zealand.

When birds have wings too short for flight, we marvel less at their restricted range; and particular genera of brevipennate birds have their peculiar continents and islands. The long and strong-limbed ostrich courses over the whole continent of Africa and conterminous Arabia. The genus of three-toed ostriches (rhea) is similarly restricted to South America. The emeu (Dromaius) has Australia assigned to it. The continent of the cassowary (Casaurius) has been broken up into Sumatra, Java, Banda, and other islands, extending from the south-eastern peninsula of Asia to New Guinea. A second species of cassowary has recently been imported to our zoological gardens from the more southern island of New Britain. The singular nocturnal wingless kivi (apteryx), is peculiar to the island of New Zealand.

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

In New Zealand also there existed, within the memory of the Maori ancestry, huge birds having their nearest affinities to the still existing apteryx of that island, but generically distinct from that and all other known birds. I have proposed the name of Dinornis for this now extinct genus, of which more than a dozen well-defined species have come to my knowledge, all peculiar to New Zealand, and the last discovered the strangest, by reason of the elephantine proportions of its feet. A tridactyle wingless bird of another genus, Æpyornis, second only to the gigantic Dinornis in size, appears to have only recently become extinct—if it be extinct—in the island of Madagascar. The egg of this bird, which may have suggested to the Arabian voyagers, attaining Madagascar from the Red Sea, the idea of the Roc of their romances, would hold the contents of six eggs of the ostrich, sixteen eggs of the cassowary, and one hundred and forty-eight eggs of the common fowl.

Had all the terrestrial animals that now exist diverged from one common centre within the limited period of a few thousand years, it might have been expected that the remoteness of their actual localities from such ideal centre would bear a certain ratio with their respective powers of locomotion. With regard to the class of birds, one might have expected to find that those which were deprived of the power of flight, and were adapted to subsist on the vegetation of a warm or temperate latitude, would still be met with more or less associated together, and least distant from the original centre of dispersion situated in such a latitude. But what is the fact? The species of no one order of birds is more widely dispersed over the earth than the wingless or struthious kind. Assuming that the original centre has been somewhere in the southwestern mountain range of Asia, there is but one of the species of flightless birds whose habitat can be reconciled with the hypothesis. By the neck of land still uniting Asia with Africa, the progeny of the primary pair created or liberated at the hypothetical centre might have traveled to the latter continent, and there have propagated and dispersed themselves southward to the Cape of Good Hope. It is remarkable, however, that the ostrich should not have migrated eastward over the vast plains or steppes which extend along the warmer temperate zone of Asia, or have reached the southern tropical regions; it is in fact scarcely known in the Asiatic continent, being restricted to the Arabian deserts, and being rare even in those parts which are most contiguous to what I have called its proper continent, Africa. If we next consider the locality of the cassowary, we find great difficulty in conceiving how such a bird could have migrated to the islands of Java, the Moluccas, or New Guinea, from the continent of Asia. The cassowary is not web-footed like the swimming birds; for wings it has only a few short and strong quills. How could it have overcome the obstacles which some hundreds of miles of ocean would present to its passage from the continent of Asia to those islands? If the difficulty already be felt to be great in regard to the insular position of the cassowary, it is still greater when we come to apply the hypothesis of dispersion from a single centre to the dodo of the island of Mauritius, or the solitaire of the island of Rodriguez. How, again, could the emeu have overcome the natural obstacles to the migration of a wingless terrestrial bird from Asia to Australia? and why should not the great continent of Asia have offered in its fertile plains a locality suited to its existence, if it ever at any period had existed on that continent? A bird of the nature of the emeu was hardly less likely to have escaped the notice of scientific travelers than the ostrich itself; but, save in the Arabian deserts, the ostrich has not been found in any part of Asia, and no other species of wingless birds has ever been met with on that continent; the evidence in regard to such large and conspicuous birds is conclusive to that fact. Again, in order that the rhea, or three-toed ostrich, should reach South America by traveling along that element on which alone it is organized and adapted to make progress, it must, on the hypothesis of dispersion from a single Asiatic centre, have traveled northward into the inhospitable wilds of Siberia; it must have braved and overcome the severer regions of the Arctic zone; it must have maintained its life with strength adequate to the extraordinary power of walking and running more than a thousand miles of land or frozen ocean utterly devoid of the vegetables that now constitute its food before it could gain the northern division of America, to the southern division of which it is at present and seems ever to have been confined. The migration in this case could not have been gradual and accomplished by successive generations. No individual of the large vegetable-feeding wingless bird that now subsists in South America could have maintained its existence, much less hatched its eggs, in Arctic latitudes, where the food of the species is wholly absent. If we are still to apply the current hypothesis to this problem in natural history, we must suppose that the pair or pairs of the rhea that started from the highest temperate zone in Asia capable of maintaining their life must have also been the same individuals which began to propagate their kind when they reached the corresponding temperate latitude of America. But no individuals of the rhea have remained in the prairies or in any part of North America—they are limited to the middle and southern division of the South American continent. And now, finally, consider the abode of the little apteryx at the Antipodes, in the comparatively small insulated patch of dry land formed by New Zealand. Let us call to mind its very restricted means of migration—the wings reduced to the minutest rudiments, the feet webless like the common fowls, its power of swimming as feeble! How could it ever have traversed six hundred miles of sea that separate it from the nearest land intervening between New Zealand and Asia? How pass from the southern extremity of that continent to the nearest island of the Indian Archipelago, and so from member to member of that group to Australia—and yet leave no trace behind of such migration by the arrest of any descendants of the migratory generations in Asia itself, or in any island between Asia and New Zealand?

If these facts are inexplicable on the hypothesis of the dispersion of the species of the air-breathing animals from a single Asiatic centre, we must next endeavor to collect analogous facts and classify them, and so try to explain intelligibly, that is agreeably with the facts, the true law or cause of the actual geographical distribution of animals.

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

The Quadrumana, or order of apes, monkeys, and lemurs, consist of three chief divisions—Catarhines, Platyrhines, and Strepsirhines. The first family is peculiar to the Old World; the second to South America; the third has the majority of its species and its chief genus (Lemur) exclusively in Madagascar. Out of twenty-six known species of Lemuridæ, only six are Asiatic and three are African.

The Catarhine monkeys include the Macaques, most of which are Asiatic, a few are African and one European; the Cercopitheques, most of which are African and a few Asiatic; and other genera which characterize one or other continent exclusively. Thus the true baboons (Papio) are African, as are the thumbless monkeys (Colobus) and the chimpanzees (Troglodytes). The Semnopithecus, gibbons, and orangs are peculiarly Asiatic. Palæontology has shown that a macaque, a gibbon, and an orang existed during the older Tertiary times in Europe, and that Semnopithecus existed in Miocene times in India. But all the fossil remains of Quadrumana in the Old World belong to the family Catarhina, which is still exclusively confined to that great division of dry land. The tailless macaque

(Innus silvanus) of Gibraltar may have existed in that part of the Old World before Europe was separated by the Straits of Gibraltar from Africa. Fossil remains of Quadrumana have been discovered in South America; they indicate Platyrhine forms: a species, for example, allied to the howlers (Mycetes), but larger than any now known to exist, has left its remains in Brazil.

While adverting to the geographical distribution of Quadrumana, I would contrast the peculiarly limited range of the orangs and chimpanzees with the cosmopolitan powers of mankind. The two species of orang (Pithecus) are confined to Borneo and Sumatra; the two species of chimpanzee (Troglodytes) are limited to an intertropical tract of the western part of Africa. They appear to be inexorably bound by climatal influences regulating the assemblage of certain trees and the production of certain fruits. With all our care, in regard to choice of food, clothing, and contrivances for artificially maintaining the chief physical conditions of their existence, the healthiest specimens of orang or chimpanzee, brought over in the vigor of youth, perish within a period never exceeding three years, and usually much shorter in England. By what metamorphoses, may we ask, has the alleged humanized chimpanzee or orang been brought to endure all climates? The advocates of transmutation have failed to explain them. Certain it is that those physical differences in cerebral, dental, and osteological structure which place, in my estimate of them, the genus Homo in a distinct group of the mammalian class, zoologically of higher value than the order, are associated with equally contrasted powers of endurance of different climates, whereby man has become a denizen of every part of the globe from the Torrid to the Arctic zones.

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

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

The camelopard is now peculiar to Africa; the musk-deer to Africa and Asia; out of fifty defined species of antelope, only one is known in America, and none in the central and southern divisions of the New World. The bison of North America is distinct from the bison of Europe. The musk-ox alone, peculiar for its limitation to high northern latitudes, roams over the Arctic coasts of both Asia and America. The deer tribe are more widely distributed. The camels and dromedaries of the Old World are represented by the llamas and vicunas of the New. As, in regard to a former (Tertiary) zoological period, the fossil Camilidæ of Asia are of the genus Camilus, so those of America are of the genus Auchenia. This geographical restriction ruled prior to any evidence of man's existence.

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

With respect to the hog tribe, we find that the true swine (Sus) of the Old World are represented by peccaries (Dicotyles) in the New; and geology has recently shown that Tertiary species of Dicotyles existed in North as well as South America. But no true Sus has been found fossil in either division of the New World, nor have the Dicotyles been found fossil in the Old World of the geographer. One of the earliest forms of the European rhinoceros was devoid of the nasal weapon.

Geology gives a wider range to the horse and elephant kinds than was cognizant to the student of living species only. The existing Equidæ and Elephantidæ properly belong, or are limited, to the Old World; and the elephants to Asia and Africa, the species of the two continents being quite distinct. The horse, as Buffon remarked, carried terror to the eye of the indigenous Americans, viewing the animal for the first time, as it proudly bore their Spanish conqueror. But a species of Equus coexisted with the

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

I have received evidences of elephantine species from China and Australia, proving the proboscidian pachyderms to have been the most cosmopolitan of hoofed herbivorous quadrupeds. Geology extends the geographical range of the sloths and armadillos from South to North America; but the deductions from recent rich discoveries of huge terrestrial forms of sloth, of gigantic armadillos, and large anteaters go to establish the fact that these peculiar features of the order Bruta have ever been, as they are now, peculiar to America; that several genera, including the larger species, have perished; and that the range of their still existing diminutive representatives has been reduced to the southern division of the New World.

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

One genus of Marsupialia (Didelphys or opossums, properly so called) is peculiar to America, and is there the sole representative of the order. A small kangaroo, and a few phalangers, exist in islands that link the Malayan Archipelago with the Australian world. All the other marsupial genera are found in Australasia, comprising New Guinea, Australia, and Tasmania. The largest and most destructive of carnivorous marsupials are peculiar to Tasmania.

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

In the Miocene and Eocene tertiary deposits, marsupial fossils of the American genus Didelphys have been found, both in France and England; and they are associated with tapirs like that of America. In a more ancient geological period, remains of marsupials, some insectivorous, others with teeth, have been found in the upper Oolite.

Thus it would seem that the deeper we penetrate the earth, or, in other words, the further we recede in time, the more completely we are absolved from the present laws of geographical distribution.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS.—William Hughes

THE great division of the animal kingdom recognized by naturalists is that into vertebrate and invertebrate animals. Vertebrated animals are those which possess a spinal bone, to which are attached ribs, constituting the framework of the entire body. All animals of this division have red blood. The vertebrate animals comprehend fishes, reptiles, birds, and mammalia. This last term is inclusive of all animals that suckle their young, man among the number.

The class mammalia comprehends the following orders: 1. Carnivora (*flesh-eating*, as the lion, tiger, etc.); 2. Ruminantia (*animals that chew the cud,* as the camel, ox, sheep, and others); 3. Pachydermata (*thick-skinned*, as the elephant, horse, etc.); 4. Rodentia (*gnawing,* as the beaver, squirrel, mice, etc.); 5. Edentata (*toothless,* as the anteater and armadillo); 6. Quadrumma (*four-handed,* as the ape and monkey tribe); 7. Cherioptera (having *winged arms,* as bats); 8. Marsupialia (*pouched,* as the kangaroo and opossum); 9. Cetaceæ (whales, dolphins, and the various seals). The last-mentioned of these divisions includes members (and those the largest) of a tribe assigned in popular language to a distinct division of the animal world—fishes. But the whale and other creatures of its order possess the distinguishing attribute of the mammalia—that is, they afford their nutriment from the breast.

The animals belonging to the ruminating and pachydermatous orders are further distinguished as ungulata, or hoofed, from the well-known characteristic of their extremities. The domesticated animals that are used as food by man are almost exclusively derived from this class. The animals included within the other orders of mammalia are designated as unguiculata, from their extremities terminating in claws, or nails.

The invertebrate animals, or those which have no spinal bone, all have white blood. They are scientifically divided into molluscous animals, in which the muscles are attached to the skin, with or without the protection of a shell—such as snails and slugs; articulated animals, in which the covering of the body is divided into rings or segments, to the interior of which the muscles are attached—comprehending all insects and worms; and radiated animals, in which the organs of motion or sensation radiate from a common centre—such as star-fish.

The opposite sides of a hill-range, even in cases where the climate is nearly identical, and the passage from one slope to the other easy, will often exhibit different conditions of animal life. Isothermal lines mark—with hardly less precision in the case of animals than of plants—the range of particular families and species, in the direction of latitude and elevation alike. The fact that such is the case testifies strongly to the force of those instincts with which all animals are endowed, and by which their habits are regulated. The powers of locomotion possessed by animals might at first sight seem calculated to favor a wider extension of geographical range than belongs to vegetables, and in the well-known instances of migratory species (of which the swallow and other birds are familiar examples) such is undoubtedly the case. But even these migrations are confined within a well-defined range, determined by conditions of climate, and facility of obtaining the necessary food. Birds in general are separated, as markedly as quadrupeds, in respect of their habitat, or geographical range. This is equally true, indeed, in regard to every one of the great classes into which the animal world is divided. Each zone of the ocean, both in latitude and in the direction of depth, has its proper forms of life.

To take an instance from land animals, the elephant is confined by natural instinct within the belt of the warm latitudes, and not more so by the high temperature which such latitudes alone enjoy than by the limitation of its necessary food to the regions which are its proper home. Nowhere else but within or near the tropics is there found the luxuriant abundance of forest vegetation which the elephant requires to make sustenance upon. The reindeer, on the other hand, is as characteristically an inhabitant of polar latitudes, and perishes if brought within the continued influence of a warmer temperature than that of his native region. The ibex and the chamois, with some other animals of the goat tribe, frequent only the highest and least accessible portions of the mountain region, while various members of the deer kind range over the lower elevations and the plains below. Of birds, the condor, or great vulture of the Andes, confines his range within the region of the highest peaks of the mountain region, as his European congener—the lammer-geyer, or vulture of the Alps—does in another part of the globe. In the mountainous portions of Great Britain, the eagles which (notwithstanding the keen pursuit of the sportsman) frequent the scarcely accessible crags that surround Loch Maree and other secluded localities of the Highlands, furnish a similar instance. Again, the shark is the well-known scourge of the warmer belt of ocean, while the same zone of sea constitutes—from its high temperature—a region through which the whale never passes.

It is, besides, equally true of the animal as of the vegetable kingdom, that every region of the globe has its own proper inhabitants, different in species, for the most part, from those of other regions. The animal life of the Old World is markedly different from that of the New World in correspondent parallels, and under conditions of climate which are in all important regards analogous. Even when the genera, or families, are the same, the species are in nearly all cases distinct. In yet higher measure, the animal life of Australia differs from that of other divisions of the globe. Whole orders of the animal world are wanting in Australian zoology, while the vast majority of its animals belong to a division which is altogether unrepresented in the continents of the Old World—that is, the marsupial tribe. The difference is less strongly marked in the case of the adjacent continents of the Northern Hemisphere than in the instances of the lands lying south of the equator.

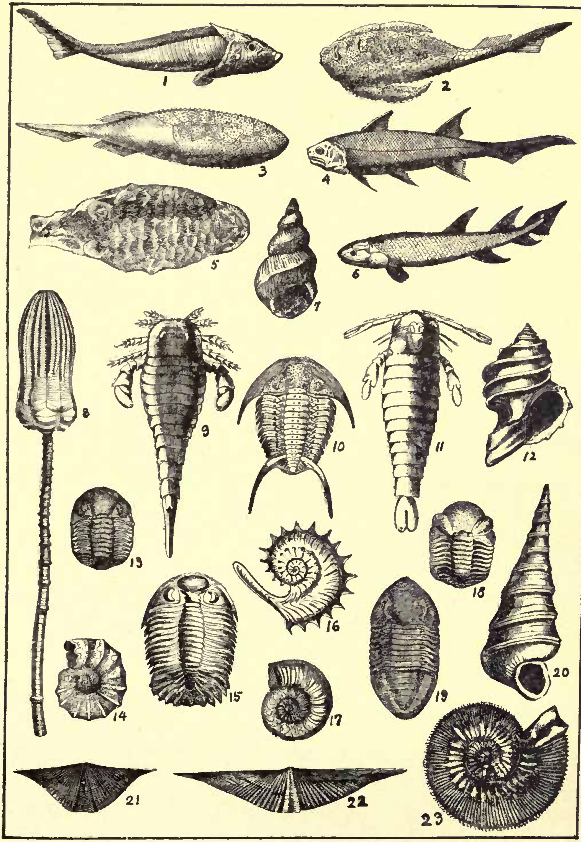
The natural distribution of animals has been importantly modified by human agency. This is especially the case in regard to those divisions of the mammalia which comprehend the domestic quadrupeds—the horse, dog, ox, sheep, and others. Man has carried these animals with him in his migrations from one region to another, and has thus introduced new species (and even genera) into lands where they were previously unknown. The horse, the ox, and the common sheep, were unknown in the New World prior to the Spanish discoveries of the Fifteenth and Sixteenth Centuries, but speedily became naturalized there, and, in the case of the two first-named, have long since reverted to a condition of nature. Wild horses roam by thousands over the savannas and pampas of the western world. Within a much more recent period, the domestic cattle of Europe have been introduced into the Australian continent, and have multiplied there to an extraordinary degree. Efforts are now making to introduce into Australia both the camel of the Old World and the llama of South America. The hare and the rabbit of Britain have become naturalized in the more southwardly of the Australian colonies. Similar efforts are at the present time directed to the naturalization in the Australian rivers of the salmon and other fish that belong to the streams and estuaries of Europe. What has been accomplished, in these and many similar cases, by the direct efforts of man, has resulted, in the case of many of the smaller animals, from his involuntary agency, or from accidental causes. The vessel which conveys a cargo of native produce from one region to a foreign shore has often carried with it the germs of life (vegetable as well as animal), besides, in numerous instances, the smaller members themselves of the animal world. The insects that were originally confined to one region have thus become distributed over wide areas of the globe.

A few other of the more obvious differences between the native zoology of the Old and New Worlds may be adverted to with advantage. Among carnivorous quadrupeds, the lion, tiger, leopard, panther, and hyena are confined to the eastern half of the globe. In the New World, the puma and the jaguar take respectively the places of the lion and tiger of the Asiatic continent. Of the ruminants, the camel, the giraffe, and the numerous antelopes are only found within the Old World. Of the pachydermata, the elephant, the rhinoceros, the hippopotamus, the horse, the zebra, and the ass are unknown to the native zoology of the lands lying west of the Atlantic. The elephant, and also the rhinoceros, belong to Asia and Africa (the species being different in the case of either continent), the hippopotamus is African only: the zebra (with its kindred species, the quagga) is also peculiar to Africa. Both the horse and the ass probably came originally from Asia. Of the Quadrumana, which are numerously represented in the zoology of either hemisphere, the species (and, in most cases, the genera) are distinct. Again, the opossums of the New World belong to an order (the marsupial) which is altogether unrepresented in the three continents of the Old World, but which exhibits its fullest development in the Australian division of the globe. Numerous other instances might be adduced, but these will suffice. They serve to show that, in the case of animals as of plants, particular regions constitute centres of particular forms of life, which thence spread, within certain limits, around, still leaving to each such region its strongly marked and typical characteristics in such regards.

Europe exhibits, in its indigenous zoology, a character less marked and distinctive than belongs to other divisions of the globe. This is in some degree the result of its dense population, and the consequent diminution in the number of wild species, but in a more special manner results from its conditions of geographical form and position. Europe is less a continent in itself than an outlying portion of the vast and unbroken mass of the Asiatic continent.

No strongly marked feature intervenes between the plains of eastern Europe and those of northern Asia, and within the continuous range of land that extends, under the same parallels, from the Baltic Sea eastward to the waters of the Pacific Ocean, the animal life exhibits for the most part identity of species and genera. The differences between them, in a vast number of instances, are merely varieties. Many of the fur-bearing animals are common to all the lands that lie within the Arctic circle, as many as twenty-seven species being native to Europe, Asia, and North America alike.

The vast population of Europe has necessitated the rearing of the domestic quadrupeds in vast numbers, and has been accompanied, in numerous instances, by the extermination of the wild denizens of the forest. It would seem from a passage in Herodotus (book vii, 125) that the lion once frequented the woods of Macedonia. The wild boar, bear, and the wolf were formerly natives of the British Islands, and the last named animal has only been exterminated from within their limits during the last hundred and fifty years. The beaver, long since banished, was once common on the banks of the Welsh streams. The fox is only preserved by artificial means, and for the purposes of the chase. The wildcat, now rarely seen, and that only in the remoter portions of the Scotch Highlands, was formerly common within the English forests. The bustard, a bird now rarely seen, was once met with in huge flights on the plains of Norfolk and Suffolk, while huge fen-eagles frequented the marshy flats of the adjacent country.



Extinct Fishes, Mollusca, and Crustacea

1, Cepha'aspis; 2, Pterichthys; 3, Coccocosteus; 4, Diplacanthus; 5, Holoptychius; 6. Osteolepis; 7, 12, 20, Gasteropods; 8, Crinoid; 9, Eurypterus; 10, 13, 15, 18, 19, Trilobites; 14, 16, 17, 23, Cephalopods (Ammonites); 21, 22, Spirifers

These are but few instances of the way in which human agency modifies the distribution of animal life. On the continent, the extermination of a particular species is of course more difficult; in numerous cases is perhaps altogether impossible. The wolf inhabits the forests of continental Europe, from the high tracts that adjoin the Alps and the Pyrenees northward to the shores of the Baltic and White Seas. The wild boar and the bear (three species of the latter—the brown and the black in the wooded regions of the south, the white polar bear in the extreme north) are still met with. The urus or wild ox of the Lithuanian forests, regarded by naturalists as the progenitor of our common domestic cattle, is even yet found to the eastward of the Baltic.

Europe, however, has no one of the great families of mammalia that can be looked on as peculiarly its own, or, in other words, as giving it a distinctive zoology—like the antelopes of Southern and Western Asia, the numerous pachyderms of the African continent ,the llama tribe of the New World, or the marsupials of Australia. Of the total number of European mammalia, not exceeding a hundred and eighty, only fifty-eight are peculiar to this continent, and none of the larger quadrupeds is included among them.

The domesticated animals that are so numerously reared in every part of Europe have probably been, in most cases, derived from indigenous species. The urus or wild ox has been the parent of the common ox, and the wild boar of the domestic pig; the goat, and, in the extreme north, the reindeer, are also native to the European soil. The moufflon of Sardinia was perhaps the ancestor of at least some of our breeds of sheep.

The birds of Europe display a greater number and variety of species than its land animals. This is especially the case in regard to the family of aquatic birds—always most numerous in the higher latitudes. More than thirty species of the duck tribe alone belong to Northern Europe, some of them being common to the corresponding latitudes of Asia and the New World. The stork and the crane (both of migratory habits) belong to the maritime regions of Western Europe; the pelican, the spoon-bill, and the scarlet flamingo, to the shores of the Mediterranean.

Europe has fewer species (as well as fewer individuals) of the reptile kind than either of the other divisions of the globe—a happy exemption, which is due to its temperate climate. The only venomous serpents found in Europe are three species of viper, all of them confined to its southern shores: the common viper of middle and Northern Europe is innocuous. Lizards are common in the south, as many as sixty-three species being enumerated.

The waters of Europe exhibit a rich variety of fish, a vast number of them useful as to the food of man. Each of its inland seas has its own peculiar tribes, the Mediterranean basin displaying the richest diversity. Among the inhabitants of the Mediterranean are several sharks, swordfish, dolphins, and six species of tunny—the last-mentioned the largest of edible fish. The anchovy is peculiar to the Mediterranean. The seas that lie around the British Islands abound in the gregarious tribes of edible fish, as the cod, turbot, mackerel, herring, pilchard, and many others. The stromming of the Baltic is of like utility. The salmon frequents the estuaries and river-mouths throughout the coast-line of Western Europe to the northward of the Bay of Biscay, becoming more numerous as higher latitudes are reached.

The generally temperate climate of Europe secures it, for the most part, an exemption from the dense swarms of insect-life that belong to warmer latitudes. Yet between eight or nine thousand species are enumerated as native to the British Islands alone. The common honey-bee is distributed all over southern and Central Europe, and is probably indigenous. The locust is only an occasional visitor to its shores, and belongs to the other side of the Mediterranean. The silk-worm was introduced from China toward the close of the Fifth Century of our era.

Asia is rich in variety of animal life, and especially so as regards the class mammalia, all the orders of which but two (the marsupials and the edentata) are represented in its zoology. Of domesticated quadrupeds, the camel, ox, goat, and sheep, among the ruminants, with the horse, the ass, and the elephant, among pachyderms, are natives of Asia. The camel, of which there are several species, all natives of this continent, ranges from the shores of the Indian Ocean and Red Sea as far north as Lake Baikal. The reindeer and elk frequent the Siberian and Mongolian plains, migrating from the former locality southward with the approach of winter. Numerous varieties of the ox tribe (including the common ox, aurochs, buffalo, and yak) are reared by the Tartar nations who inhabit the upland plains of the interior. The antelope and deer tribe, of which there are a vast number of species, belong to the western and southwestern regions of the continent. The plains of Turkestan, to the eastward of the Caspian, are perhaps the original country of the horse. The wild ass is indigenous to Western Asia. The elephant is not found to the west of India, nor to the north of the Himalaya Mountains; it belongs only to the two Indian peninsulas, with Ceylon, and some of the smaller islands of the Malay archipelago.

Among Asiatic carnivora are the lion, tiger, leopard, panther, and ounce, of the cat genus: the wolf, hyena, and jackal, of the dog tribe. Two species of bear are native to the Himalaya region (the snow-bear, and the black-bear) and the polar bear belongs to the Arctic coasts of the continent. The lion of Asia is now restricted to the region which extends from the banks of the Euphrates and Tigris to the western coasts of the Indian peninsula, including the deserts of Mesopotamia, Persia, and Hindostan. The tiger has a more extensive range, and inhabits all the middle and southeastern divisions of the continent. The hyena, and also the jackal, belong to the western half of Southern Asia; the wolf frequents the northern and western plains, and is found in a range of country extending from Siberia, through Turkestan, to the shores of the Mediterranean. The dog and the fox are common all over the continent, and present numerous varieties; in Kamtchatka and some parts of Siberia, the former animal is used as a beast of burden, and is trained to draw the sledges over the vast plains of ice and snow.

Numerous fur-bearing animals occur in Siberia, including the bear, glutton, badger, wolf, fox, lynx, pole-cat, weasel, ermine, marten, otter, sable, squirrel, beaver, hare, and the reindeer: many of these belong also to the northern regions of Europe. The quadrumana are found in the south and southeast of the continent and the islands of the Malay archipelago; the largest and most remarkable among them —the orang-outang—is restricted to the Malayan peninsula and the islands of Borneo and Sumatra. The gibbons (or long-armed apes) belong exclusively to Asia, and abound in its southeastern parts. Bats are more numerous in the islands of the Asiatic archipelago than on the continent.

Asia is less rich in variety of birds than in quadrupeds, but (with the exception of the turkey, which is a native of the New World, and of the guinea-fowl, which is African) all our domestic poultry came originally from this division of the globe. Among its birds of prey are eagles, vultures, falcons, owls, and hawks; but although individually abundant, the species of these are not numerous. Song-birds are numerous in western Asia, but are comparatively scarce in the eastern division of the continent, where, however (especially among the islands of the Malay archipelago and in China), birds of beautiful plumage abound. The peacock is a native of India, the golden pheasants belong to China, and the birds of paradise to New Guinea and the adjacent islands.

Reptiles are less numerous in Asia than in some other parts of the globe, but are sufficiently common in the southeastern parts of the continent and the adjacent islands. The python (analogous to the boa-constrictor of the New World) lurks in the morasses and swamps of the East Indian islands; the cobras, with several other kinds of venomous serpents, are found in the peninsulas of Eastern and Western India. Both sea and fresh-water snakes are numerous. Among insects, the locust is abundant in Western Asia, and commits the most dreadful ravages among the crops in Syria, Persia, and Arabia.

Africa is yet richer than Asia in regard to the animal kingdom. Of the total number of mammalia, more than a fourth occur in this division of the Old World, and fewer than a sixth of the number are common to Africa with either of the other continents. It is in the carnivora, ruminants, pachyderms, and quadrumana, that African zoology is more especially rich. Only one order, the marsupial, is unrepresented in it. Nor is the varied abundance of animal life in this region of the globe confined to species; the development of individual life within its vast and almost boundless solitudes is yet more characteristic.

Among African beasts of prey are the lion, panther, leopard, wolf, fox, hyena, and jackal. Three varieties of the lion occur—that of Northern Africa, of the countries on the Senegal, and of the extreme south, toward the Orange River. There are two hyenas—one, the spotted hyena, a native of Southern Africa; the other, the striped hyena, indigenous to the more northerly parts of the continent, and extending its range from Abyssinia and Barbary into Western Asia. The wolf and the jackal belong to Northern Africa.

Of ruminants, there are no less than sixty species of the antelope kind, which is especially abundant in Southern Africa. The cameleopard or giraffe is peculiar to this continent, and ranges from the banks of the Gariep to the southern borders of the Sahara, but is not found upon the western coasts. Several species of buffalo occur in a wild state, and are most abundant within the outlying districts of the Cape Colony. Sheep and goats abound in most parts of Africa, but are probably not indigenous; both in Barbary and near the Cape of Good Hope—at the opposite extremities of the continent—are found sheep with broad, fat tails, so large as sometimes to weigh from ten to thirty pounds. The camel of Africa is found all over its northern and central regions.

Of the Pachydermata, or thick-skinned animals, the most characteristic are the elephant, rhinoceros, and hippopotamus. The elephant is found dispersed, in immense herds of from one to three hundred, all over the wooded regions of Central and Southern Africa, and the rhinoceros frequents principally the same localities. The ivory supplied by the tusks of the former is one of the most valuable native products of this quarter of the globe. The rhinoceros is valued chiefly for its hide, which is made into shields and harness. The hippopotamus is found in the upper part of the Nile valley, and in all the lakes and rivers to the southward of the Great Desert—including the Senegal, the Gambia, the Congo, and the Gariep. This animal is peculiar to Africa; its teeth consist of the finest ivory, for the sake of which it is hunted by the settlers of the Cape. All three of these animals are used as food by the native races of the South African interior.

The wild boar is found in some parts of Africa: the zebra, dow, and quagga (all peculiar to this continent) abound in its central and southern regions, particularly in the arid plains in the neighborhood of the Orange River. Of the African Quadrumana, monkeys, baboons, apes, and lemurs abound in the forests throughout every part of the continent.

The chimpanzee of the western coasts (from the neighborhood of Sierra Leone to the 10th parallel of S. latitude) makes nearer approach to the human form than the orang-outang of Southeastern Asia, but is surpassed in this respect by the gorilla, one of the largest of the ape tribe, which inhabits the forests in the neighborhood of the Gaboon River (0° 30′ N. lat.).

Bats are numerous in Africa, and most of the species inhabiting this continent are peculiar to it. The Rodentia are also for the most part of peculiar species; among them are hares, rabbits, jerboas, squirrels, rats, and mice.

Among birds, the ostrich is confined to Africa, but ranges from its southern extremity to the northern borders of the Great Desert. Its feathers form a highly valued article of traffic, and the bird is domesticated in many parts of Africa for the sake of procuring these free from injury. The vulture (of which two species occur—one in Northern Africa and the other in the neighborhood of the Cape) serves here, as elsewhere, to preserve the air from impurity, by feeding on the carcasses of animals, and divides with the hyena the office of scavenger. The owl, falcon, and eagle are also enumerated among the African birds of prey. Of gallinaceous birds Africa possesses only the guinea-fowl; but the domestic poultry are numerously reared, though not indigenous. The woods of tropical Africa abound in numberless varieties of parrots and paroquets, besides many other birds of bright and gaudy plumage—as the beautiful sun-birds (which inhabit the western coasts, and are scarcely larger than the humming-birds of America), together with the golden-colored orioles, crested hoopoes, bee-eaters, and others. The honey-suckers, which abound in the neighborhood of the Cape of Good Hope, feed entirely upon the nectar or saccharine juice of the proteas and similar plants. The sun-birds also occur in Southern Africa, and rival those of India and the Gambia in the brilliancy of their colors.

Lizards, serpents, and reptiles of every description abound in various parts of the African continent, though its general aridity, throughout extensive regions, is less favorable to the development of reptile life than in the case of correspondent latitudes elsewhere. The crocodile inhabits all the large rivers of tropical Africa, and is abundant in the lower portion of the Nile. The huge python, sometimes twenty-two feet in length (though inferior in size to the boa of the New World), is found in the swamps and morasses of the western coast, and some species of the cobra (or hooded snake) occur—chiefly in Southern Africa and on the shores of Guinea. Insects abound, both in species and as individuals; among them is the locust, which at intervals ravages all the northern parts of the continent. But the termites, or white ants, of Western Africa are the most celebrated members of the insect family, and effect the most extraordinary destruction of furniture, books, clothes, food, and everything that comes in their way. They build pyramidal or conical nests, firmly cemented together, and divided into several apartments—so large that at first sight they appear in the distance like the villages of the natives. Both the bee and the wasp are numerously distributed, but the bee has not been domesticated by any of the native people of this continent; it is, however, reared by the Arabs in Northern Africa.

The New World exhibits, through its vast prolongation in the direction of latitude, a development of animal life which is almost infinitely varied, and which differs in many essential regards from that belonging to either of the continents of the Eastern Hemisphere. Each of the nine orders of Mammalia is represented within its limits, but many of the most attractive and valuable members of the animal life of Asia and Africa are nevertheless wanting. America has neither the elephant nor the camel; and neither the horse, the ox, the sheep, nor the hog is indigenous to it.

The Carnivora of the New World are inferior in size, strength, and ferocity to those of Asia and Africa. In place of the lion, America has only the puma—a smaller and less powerful creature. The tiger of Southern Asia is represented by the jaguar, a somewhat smaller animal, but the most powerful of the American carnivora. In North America, however, the numerous bears are distinguished by their size and power, particularly the grizzly bear of the countries which border upon the Rocky Mountains. The great white bear of the polar regions is common to the high latitudes of either hemisphere. North America, which is more strictly continental in extent than the southern half of the New World, possesses, indeed, other types of animal life which rival those of the Eastern Hemisphere. Among these are the majestic bison, or American buffalo, together with the elk or moose-deer, occupying a place similar to the reindeer of Northern Europe and Asia. Several varieties of the deer-kind occur in the northern half of the continent, together with the musk-ox, the big-horned sheep, and the Rocky Mountain goat, which are peculiar to this region.

The tapir and the peccary (an animal of the hog kind) range all over the plains of South America, and the former is also found on the coast of Central America. The puma (or cougar) occurs on the Mexican Isthmus, and even as far northward as the 45th parallel, though found most numerously in the southern half of the continent, where its range extends to within a few degrees of the Strait of Magellan. The jaguar is found in the coast regions of the Mexican Isthmus, as well as the forests of Brazil and the adjoining regions of South America. The lynx and the wolf belong to the colder tracts of North America.

The opossums are numerous in South America, and one species is met with in the United States (Virginia); this family (Marsupialia) is altogether absent from the eastern continent, but is fully developed in the Australian division of the globe. The beaver abounds in the colder latitudes of North America, together with a vast number of other fur-bearing animals; as raccoons, martens, squirrels, sea-otters, minks, muskrats, ermines, foxes, wolverines, and hares.

The llama tribe (comprehending, besides the llama, the alpaca, vicuna, and others), is peculiar to South America. Its members are found throughout the prolonged cordilleras of the western side of that continent, from Chili to New Granada, dwelling always at considerable heights above the level of the sea. The llama belongs to the same order (Ruminantia) as the camel of the Old World, and supplies some of the uses of that animal as a beast of burden. Prior to the Spanish conquest, the llama was, indeed, the only beast of burden which the natives of South America possessed. The tapir of the same continent (an animal about the size of a small cow, and readily distinguished by the downward bend of its snout) belongs to the order of pachyderms. Two species of tapir, both of them peculiar to that region, inhabit South America: a third species is native to the island of Sumatra, and the adjacent Malay peninsula, in Southeastern Asia.

The paca and cutia (or agouti) both of a family which is peculiar to South America, take the place of the hare and rabbit of the Old World, and belong, like those animals, to the order of rodents. Both are used as food. The capybara and the common guinea-pig belong to the same order. The chinchilla, another of the South American rodents, valued for its delicate fur, is confined to the southern portions of the Andes.

The sloth, ant-eater, and armadillo (all belonging to the order of Edentata), are natives of South America.

Monkeys are exceedingly numerous all over that continent, especially in the forests of Brazil. These, however, are different in species from the monkeys of the Eastern Hemisphere; they are of smaller size, and (with the exception of one nearly tailless species, found within the forests of the Upper Amazons, within a very limited area) all possess tails, mostly prehensile. None of the apes of the New World makes the same approach to the human form which is found either in the chimpanzee and gorilla of Western Africa or the orang of Southeastern Asia. Toward the close of the day the howling monkeys of Brazil make the woods resound with the most frightful cries; but they are neither of large size nor of formidable powers. The family of lemurs, so abundant in the eastern half of the globe, has not a single representative in the New World. The marmosets, a family confined to America, are numerous within the regions of the lower Amazons.

Bats are very numerous in South America—more so than in any other part of the world: among them is the large vampire-bat, to which popular rumor has assigned the most bloodthirsty propensities, though it is in reality perfectly harmless, feeding chiefly upon fruits, with a few insects. All the American bats differ in species from those of the eastern continent.

The ornithology of tropical America exceeds in splendor that of any other region of the globe. Among the principal birds of prey are several species of eagle, including the large white-headed eagle of the United States, with vultures, hawks, kites, and owls. South America, however, possesses the largest of the vulture tribe—the gigantic condor of the Andes, which is confined to the higher peaks of those mountains, bordering on the limits of the snowy region. This is one of the most powerful and rapacious of birds, and commits numerous ravages among the cattle, deer, and other animals. The American ostrich, or emu, which dwells in the pampas of that region, is also distinguished by its size. The turkey is American, and is the only one of the domestic poultry that has been derived from the New World.* The toucans, distinguished by their enormous bills, are peculiar to America.

* The turkey had been domesticated by the Mexicans, from whom the Spaniards introduced it into Europe. It had already become tolerably common in England before the close of the Sixteenth Century, and in Spain and the south of Europe much earlier in date.

The potato, maize, the cinchonas, tobacco, and the turkey, have been pronounced the five great gifts of the New World to the Old.

The humming-birds are peculiar to the western continent, and in the tropical regions of America various birds of the most glittering plumage, together with numberless fire-flies, lend an almost magical charm to the aspect of nature. The range of the humming-birds extends over the whole continent to the southward of the 42d parallel (north lat.) and stretches upon the western side of North America as high as the parallel of 60°—an evidence of the superior warmth which distinguishes that side of the American continent.

Both reptiles and insects are abundant in the New World, which, owing to its excessive moisture and dense vegetation, is peculiarly suited to the development of these departments of the natural kingdom. Venomous serpents are more numerous in tropical America than in any other part of the globe. The rattlesnake occurs in both divisions of the continent, within the parallels of 44° to the northward and of 30° to the south of the equator; the huge boa-constrictor, the largest of the serpent tribe, and the terror even of the natives, dwells in the marshes and swamps of South America. Huge caymans, iguanas, and other lizards, with numberless alligators and water-snakes, abound in the rivers and temporary lagoons of the same region.

Australia possesses a zoology which is more distinctive than that of any other part of the world. Its native insects, reptiles, birds, and land animals are all strikingly different from those of other regions. The difference is greatest (or, at any rate, most obvious to ordinary observation) in the case of its land animals. Two-thirds of the Australian Mammalia belong to the marsupial order, and the kangaroo, the largest member of that family, surpasses in size any other of its indigenous quadrupeds. The Quadrumana, pachyderms, and ruminants are altogether unrepresented, nor are there any of the larger carnivora, the native dog (already verging on extinction) being the chief among them. In the present day large numbers of the Australian population are employed in rearing the domestic cattle of Europe.

Australia forms in all regards a distinct zoological province, and its insulated position has tended, in greater measure than is the case with any other part of the world, to confine the distinguishing features of its fauna within its own proper limits. The kangaroo family includes numerous distinct species, from the full-sized kangaroo down to the kangaroo-rat. But not a single one of the tribe is found beyond the limits of Australia and the neighboring island of Tasmania. The opossums, which belong to the same order, are only found elsewhere in the New World. The most remarkable, however, among the members of the Australian animal world is that popularly known as the duck-bill (platypus, or ornithorynchus), which constitutes a puzzle to the naturalist. This is a semi-aquatic creature, about twelve or thirteen inches in length, with the body of an otter, a bill like that of the duck, and which lays eggs. As one of the tribe of Mammalia (to which, by its habits, it belongs), the platypus must be classed under the head of Edentata; while, on the other hand, as being oviparous, it may be regarded as belonging to a totally distinct division of the animal world. The platypus frequents the margins of creeks and pools, but remains mostly in the water, and is only approached with difficulty, on account of its extreme shyness. It has a coating of soft fur, variously shaded from black to silver-gray.

Australia is distinguished by an extreme paucity of animal life (in so far as land animals are concerned), in even a higher degree than by the limited number of its native species. This is readily explained by the generally arid character of its interior, the scantiness of the native vegetation, and the consequent difficulty of finding food. The traveler may frequently pass over many hundred miles of country without meeting with a single quadruped, and almost without finding the traces of a single land animal. Its characteristics in the latter regard are undergoing, however, a rapid change: the horse and the ox, introduced by the European settlers, have in some cases reverted to a state of nature, and a herd of wild cattle is now not infrequently met with beyond the ordinary limits of the settlers' range.

The ornithology of Australia is richer and more varied than other branches of its animal life. Its chief distinction consists in the vast proportion of suctorial birds—that is, such birds as derive their principal support from sucking the nectar of flowers. This peculiar organization, restricted in Africa, India, and America to the smallest birds in creation, is here developed very generally, and belongs to species that are as large as an English thrush. The melliphagidæ, or honey-suckers, take the place of the humming-birds of the New World: like all the family to which they belong, they have the tongue terminating in a brush-like bundle of very slender filaments, with which they suck the nectar of flowers.

Among the native Australian birds are a vast number of the parrot tribe, comprehending paroquets, cockatoos, and others, many of them distinguished by the most beautiful plumage. Of birds of prey, eagles, falcons, and hawks are numerous, as well as several owls. The largest among the feathered tribes of Australia is the emu, or cassowary—a bird of the ostrich kind, though of rather inferior size to the African ostrich. It is found chiefly in the southern portions of the continent, but is yearly becoming scarcer under the advance of the settlers.*

The scattered islands of the Pacific which, under the name of Polynesia, constitute, in modern geography, one of the divisions of the globe, can hardly be regarded as a distinct zoological region, so obviously has their animal life been derived from other lands. When first visited by European navigators, little more than a century since, the largest quadruped found in the Polynesian groups was the hog, which had probably accompanied the tribes of mankind by whom they were peopled. The only other land animals were the dog, mouse, and lizard, with

* The emu and cassowary, though in common language referred to as identical, are specifically distinct. Of the cassowary, properly so called, three distinct species are now known—one of them an inhabitant of the Australian mainland, in the neighborhood of Cape York, a second native to New Guinea, and a third inhabiting the island of New Britain.

a few rats. There were but few reptiles, or insects; fleas, scorpions, cockroaches, and other vermin have since been introduced.

The native fauna of New Zealand is hardly less scanty than that of the smaller groups of the Pacific. The largest animal found there by the first European settlers was the pig, which is probably not indigenous, though it has reverted to a state of nature. Dogs are the only beasts of prey: a few rats and mice complete the list of its Mammalia. There are no marsupials, though New Zealand is nearer by many thousand miles to Australia than to any of the other continents. The feathered tribes are equally few in number, but they include at least one species—now fast approaching extinction—the apteryx (wingless bird), which has no representative elsewhere. The moa, a bird of the ostrich kind, appears to have become extinct within the Nineteenth Century.

CETACEA.—Peter Mark Roget

REMARKABLE exemplifications of the law of uniformity of organic structure are furnished by the family of the Cetacea, which includes the whale, the cachalot, the dolphin, and the porpoise, and exhibits the most elementary forms of the type of the Mammalia, of which they represent the early or rudimental stage of development. Here, as before, we have to seek these first elements among the inhabitants of the water: for whenever, in our progress through the animal kingdom, we enter upon a new division, aquatic tribes are always found to compose the lowest links of the ascending chain. Here, also, we observe organic development proceeding with more rapidity, and raising structures of greater dimensions in aquatic than in terrestrial animals. The order Cetacea comprises by far the largest animals which inhabit the globe. Whatever may have been the magnitude of those huge monsters which once moved in the bosom of the primeval ocean, or stalked with gigantic strides across antediluvian plains, and whose scattered remains bear fearful testimony of the convulsions of a former world, certain it is that, at the present day, the whales of the northern seas are the most colossal of the living animal structures existing on the surface of this planet.

A cursory survey of the organization of the tribes belonging to this semi-amphibious family will impress us with the resemblance they bear to fishes; for they present the same oval outline of the body, the same compact form of the trunk, which is united with the head without an intervening neck; the same fin-like shape of the external instruments of motion and the same enormous expansion and prolongation of the tail, which is here also, as in fishes, the chief agent in progression. With all this agreement in external characters, their internal economy is conducted upon a totally different plan; for although constantly inhabiting the ocean, their vital organs are so constructed as to admit of their breathing only the air of the atmosphere, and the consequences which flow from this difference are of great importance. The necessity of aerial respiration compels them to rise, at short intervals, to the surface of the water; and this air, with which they fill their lungs in respiration, gives their bodies the buoyant force that is required to facilitate their ascent, and supersedes the necessity of a swimming bladder, an organ which is so useful to the fish.

With the intent of diminishing still further their specific gravity, Nature has provided that a large quantity of oily fluid shall be collected under the skin, a provision which answers, also, the purpose of preserving the vital warmth of the body. A great accumulation of this lighter substance is formed on the upper part of the head, apparently with a view to facilitate the elevation to the surface of the blowing hole, or orifice of the nostrils, which is placed there.*

Another peculiarity of conformation, in which the Cetacea differ from fishes, and which has also an obvious relation to their peculiar mode of breathing, is in the form of the tail, which, instead of being compressed laterally and inflected from side to side, as in fishes, is flattened horizontally, and strikes the water in a vertical direction, thereby giving the body a powerful impulsion, either toward the surface, when the animal is constrained to rise, or downward, when, by diving, it hastens to escape from danger.

All the essential and permanent parts of the skeleton of vertebrated animals, that is, the spinal column, and its immediate dependencies, the skull, the caudal

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* The substance called *Spermaceti* is lodged in cells, formed of a cartilaginous substance, situated on the upper part of the head of the *Cachalot.*

prolongation, and the ribs are found in that of the Cetacea. The thorax is carried very much forward, especially in the whale, and the neck is so short as to be scarcely recognizable: for the object of the conformation is here, as in that of the fish, to allow free scope for the movements of the tail and ample space for the lodgment of its muscles. For the purpose of giving greater power and more extensive attachment to these muscles, the transverse processes of the dorsal and lumbar vertebræ are expanded both in length and breadth, and, being situated horizontally, offer no impediment to the vertical flexure of the spine. For the same reason the ribs are continued in a line with the transverse processes, and articulated with their extremities, thus giving still further breadth to the trunk.

As there is a total absence of hinder extremities, so there is no enlargement of any of the vertebræ corresponding to a sacrum, and the caudal vertebræ are uninterrupted continuations of those of the trunk. They develop, however, parts which are met with only among fishes and reptiles, namely, arches composed of inferior leaves and spinous processes, inclosing and giving protection to a large artery. Although the bones of the legs do not exist, yet there are found, in the hinder and lower part of the trunk, concealed in the flesh, and quite detached from the spine, two small bones, apparently corresponding to pelvic bones, for the presence of which no more probable reason can be assigned than the tendency to preserve an analogy with the more developed structures of the same type.

A similar adherence to the law of uniformity in the plan of construction of all the animals belonging to the same class, is strikingly shown in the conformation of the bones of the anterior extremities of the Cetacea; for, although they present, externally, no resemblance to the leg and foot of a quadruped, being fashioned into fin-like members, with a flat, oval surface for striking the water, yet, when the bones are stripped of the thick integument which covers them and conceals their real form, we find them exhibiting the same divisions into carpal and metacarpal bones, and phalanges of fingers, as exist in the most highly developed organization, not merely of a quadruped, but also of a monkey, and even of man.

HUNTING AND FISHING OF ANIMALS.—Frédéric Houssay

THE search for food has necessarily been the cause of the earliest industries among animals. It is easy to understand that the herbivora need little ingenuity in seeking nourishment; they are so superior to their prey that they can obtain it and feed on it by the sole fact of an organization adapted to its assimilation. They are, it is true, at the mercy of circumstances over which they have no control, and which lead to famine. The carnivora also may have to suffer from the absence of prey, but even in the most favorable seasons, and in the regions where the animals on which they live abound, it is necessary for them to develop a special activity to obtain possession of beings who are suspicious, prompt in flight, and as fleet as themselves. Thus it is among these that we expect to find the art of hunting most cultivated; especially if we put aside the more grossly carnivorous of them, whose whole organization is adapted for rapid and effective results.

The most rudimentary method of hunting in ambush is simply to take advantage of some favorable external circumstance to obtain concealment, and then to await the approach of the prey. Some animals place themselves behind a tuft of grass, others thrust themselves into a thicket, or hang on to the branch of a tree in order to fall suddenly on the victim who innocently approaches the perfidious ambush. The crocodile, as described by Sir Samuel Baker, conceals himself by his skill in plunging noiselessly. On the bank a group of birds have alighted. They search the mud for insects or worms, or simply approach the stream to drink or bathe. In spite of his great size and robust appetite the crocodile does not disdain this slight dish; but the least noise, the least wrinkle on the surface of the water would cause the future repast to vanish. The reptile plunges, the birds continue without suspicion to come and go. Suddenly there emerges before them the huge open jaw armed with formidable teeth. In the moment of stupor and immobility which this unforeseen apparition produces a few imprudent birds have disappeared within the reptile's mouth, while the others fly away. In the same sly and brutal manner he snaps up dogs, horses, oxen, and even men who come to the river to drink.

One of the most dangerous ambushes which can be met on the road by animals who resort to a spring is that prepared by the python. This gigantic snake hangs by his tail to the branch of a tree and lets himself droop down like a long creeper. The victim who comes within his reach is seized, enrolled, pounded in the knots which the snake forms around him. It is not necessary to multiply examples of this simple and widespread method of hunting.

Not content with utilizing the natural arrangements they meet with, there are animals which construct genuine ambushes, acting thus like man, who builds in the middle or on the edge of ponds, cabins in which to await wild ducks, or who digs in the path of a lion a hole covered with trunks of trees, at the bottom of which he may kill the beast without danger. Certain insects practice this method of hunting. The fox, for instance, so skilful a hunter in many respects, constructs an ambush when hunting hares.

The larva of the tiger beetle (Cicindela campestris) constructs a hole about the size of a feather quill, disposed vertically, and of a depth, enormous for its size, of forty centimetres. It maintains itself in this tube by arching its supple body along the walls at a height sufficient for the top of its head to be level with the surface of the soil, and to close the opening of the hole. A little insect—an ant, a young beetle, or something similar—passes. As soon as it begins to walk on the head of the larva, the latter letting go its hold of the wall allows itself to fall to the bottom of the trap, dragging its victim with it.

In this narrow prison it is easily able to obtain the mastery over its prey, and to suck out the liquid parts.

The Staphilinus Cæsareus acts with still greater shrewdness; not only is his pit more perfect, but he takes care to remove all traces of preceding repasts which might render the place obviously one of carnage. He chooses a stone, beneath which he hollows a cylindro-conical hole with extremely smooth walls. This hole is not to serve as a trap, that is to say that the proprietor has no intention of causing any pedestrian to roll to the bottom. It is simply a place of concealment in which he awaits the propitious moment. No creature is more patient than this insect, and no delay discourages him. As soon as some small animal approaches his hiding-place he throws himself on it impetuously, kills it, and devours it. Near his ditch he has hollowed a second of a much coarser character, the walls of which have not been smoothed with the same care. One here sees elytra and claws piled up; they are the hard and horny parts which he has not been able to eat. The heap in this ditch is not then an alimentary store. It is the *oubliette* in which the Staphilinus buries the remains of his victims. If he allowed them to accumulate around his hole all pedestrians would come to fear this spot and to avoid it. It would be like the dwelling of a polypus, which is marked by the numerous carapaces of crabs and shells which strew the neighborhood.

The ambuscade of the ant-lion is classic; it does not differ greatly from the others. He excavates a conical pitfall, in which he conceals himself, and seizes the unfortunate ants and other insects whom ill-chance causes to roll into it.

A variety of ambush which brings the baited ambush method of hunting to considerable perfection lies in inciting the prey to approach the hiding-place instead of trusting to chance to bring it there. In such circumstances man places some allurement in the neighborhood—that is to say, one of the foods preferred by the desired victim, or at least some object which recalls the form of that food, as, for example, an artificial fly to obtain possession of certain fishes.

It is curious to find that fish themselves utilize this system; it is the method adopted by the angler and the Uranoscopus. The Uranoscopus scaber lives in the Mediterranean. At the end of his lower jaw there is developed a mobile and supple filament which he is able to use with the greatest dexterity. Concealed in the mud, without moving and only allowing the end of his head to emerge, he agitates and vibrates his filament. The little fishes who prowl in the neighborhood, delighted with the sight of this apparent worm, regarding it as a destined prey, throw themselves on to it, but before they are able to bite and recognize their error they have disappeared in the mouth of the proprietor of the bait.

The angler (Lophius piscatorius) has not usurped his rather paradoxical name. He retires to the midst of the sea-weed and algæ. On his body and all round his head he bears fringed appendages which, by their resemblance to the leaves of marine plants, aid the animal to conceal himself. The color of his body also does not contrast with neighboring objects. From his head arise three movable filaments formed by three spines detached from the upper fin. He makes use of the anterior one, which is the longest and most supple. Working in the same way as the Uranoscopus, the angler agitates his three filaments, giving them as much as possible the appearance of worms, and thus attracting the little fish on which he feeds.

All these methods of hunting or of fishing by surprises are for the most part practiced by the less agile species which can not obtain their prey by superior fleetness. Midway between these two methods may be placed that which consists in surprising game when some circumstance has rendered it motionless. Sometimes it is sleep which places it at the mercy of the hunter, whose art in this case consists in seeking out its dwelling. Sometimes he profits by the youth of the victim, like all bird-nesters, whose aim is to eat the eggs or to devour the young while still incapable of flying. The animals who eat birds' eggs are numerous both among mammals and reptiles, as well as among birds themselves.

The alligator of Florida and of Louisiana delights in this chase. He seeks in particular the great boat-tail (Quiscalus major) which nests in the reeds at the edge of marshes and ponds. When the young have come out and are expecting from their parents the food which the chances of the hunt may delay, they do not cease chirping and calling by their cries. But the parents are not alone in hearing these appeals. They may also strike the ears of the alligator, who furtively approaches the imprudent singers. With a sudden stroke of his tail he strikes the reeds and throws into the water one or more of the hungry young ones, who are then at his mercy.

The animals who feed on species living in societies either seize on their prey when isolated or when all the members of the colony are united in their city. A search for the nest is necessary in the case of creatures who are very small in comparison with the hunter, as in the case of ants and the ant-eater. But the ant-eater possesses a very long and sticky tongue, which renders the capture of these insects extremely easy; when he finds a frequented passage it is enough to stretch out his tongue; all the ants come of their own accord and place themselves on it, and when it is sufficiently charged he withdraws it and devours them. The African Orycteropus, who is also a great eater of ants and especially of termites, is equally aided by a very developed tongue; but he has less patience than the ant-eater, and he adds to this resource other proceedings which render the hunt more fruitful and enable him to obtain a very large number of insects at one time. Thanks to his keenness of scent he soon discovers an ant-path bearing the special and characteristic odor which these Hymenoptera leave behind them, and he follows the track which leads to their nest. On arriving there, without troubling himself about the scattered insects that prowl in the neighborhood, he sets himself to penetrate into the midst of the dwelling, and with his strong claws hollows out a passage which enables him to gain access. On the way he pierces walls, breaks down floors, gathering here and there some fugitives, and arrives at last at the centre, in which millions of animals swarm. He then swallows them in large mouthfuls and retires, leaving behind him a desert and a ruin in the spot before occupied by a veritable palace, full of prodigious activity.

The colonies are not only exposed to the devastations of those who feed on their members; they have other enemies in the animals who covet their stores of food. The most inveterate robber of bees is the nocturnal Death's Head moth. When he has succeeded in penetrating the hive the stings of the proprietors who throw themselves on him do not trouble him, thanks to his thick fleece of long hairs which the sting can not penetrate; he makes his way to the cells, rips them open, gorges himself with honey, and causes such havoc that in Switzerland, in certain years when these butterflies were abundant, numbers of hives have been found absolutely empty. Many other marauders and of larger size, such as the bear, also spread terror among these laborious insects and empty their barns. No animal is more crafty than the raven, and the fabulist who wished to make him a dupe was obliged to oppose to him the very cunning fox in order to render the tale fairly life-like. A great number of stories are told concerning the raven's cleverness, and many of them are undoubtedly true. There is no bolder robber of nests. He swallows the eggs and eats the little ones of the species who can not defend themselves against him; he even seeks the eggs of sea-gulls on the coast; but in this case he must use cunning, for if he is discovered it means a serious battle. On the coast also the raven seeks to obtain possession of the hermit-crab. This crustacean dwells in the empty shells of gasteropods. At the least alarm he retires within this shell and becomes invisible, but the bird advances with so much precaution that he is often able to seize the crab before he has time to hide himself. If the raven fails he turns the shell over and over until the impatient crustacean allows a claw to emerge; he is then seized and immediately devoured.

If there is a question of hunting larger game like a hare, the raven prefers to take an ally. They start him at his burrow and pursue him flying. In spite of his proverbial rapidity the hare is scarcely able to flee more than two hundred yards. He succumbs beneath vigorous blows on his skull from the beaks of his assailants. During winter, in the high regions of the Alps, when the soil is covered with snow, this chase is particularly fruitful for ravens. The story is told of that unfortunate hare who had hollowed out in the snow a burrow with two entrances. Two of these birds having recognized his presence, one entered one hole in order to dislodge the hare, the other awaited him at the other opening to batter his head with blows from his beak and kill him before he had time to gain presence of mind.

Rooks sometimes hunt in burrows by ingeniously concerted operations. Mr. Bernard has described the interesting way in which the rook hunts voles or field-mice in Thuringia. His curiosity was excited by the way in which numerous rooks stood about a field cawing loudly. In a few days this was explained: the field was covered with rooks; the original assemblage had been calling together a mouse-hunt, which could only be successfully carried out by a large number of birds acting in conjunction. By diligently probing the ground and blocking up the network of runs, the voles, one or more at a time, were gradually driven into a corner. The hunt was very successful, and no more voles were seen in that field during the winter.

Other animals are not easily discouraged by the swiftness of their prey; they count on their own resistance in order to tire the game; some of them also manage their pursuit in the most intelligent way, so as to preserve their own strength while the tracked animal's strength goes on diminishing until exhaustion and fatigue place him at their mercy.

Mammals especially, such as dogs, wolves, and foxes, exercise this kind of chase; it is, exactly, the coursing which man has merely had to direct for his own benefit. Wild dogs pursue their prey united in immense packs. They excite each other by barking while they frighten the game and half paralyze his efforts. No animal is agile and strong enough to be sure of escaping. They surround him and cut off his retreat in a most skilful manner; gazelles and antelopes, in spite of their extreme nimbleness and speed, are caught at last; boars are rapidly driven into a corner; their vigorous defence may cost the life of some of the assailants, but they nevertheless become the prey of the band who rush on to the quarry. In Asia wild dogs do not fear even to attack the tiger.

Wolves hunt also in considerable bands. Their audacity, especially when pressed by hunger in the bad season, is well known. In time of war they follow armies, to attack stragglers and to devour the dead. In Siberia they pursue sledges on the snow with terrible perseverance, and the pack is not delayed by the massacre of those who are shot. A few stop to devour at once their fallen comrades, while the others continue the pursuit.

Besides these brutal chases wolves seem able to exercise a genuine feint. Sometimes it is a couple who hunt in concert. If they meet a flock, as they are well aware that the dog will bravely defend the animals intrusted to him, that he is vigilant, and that his keen scent will bring him on them much sooner than the shepherd, it is with him that they first occupy themselves. The two wolves approach secretly; then suddenly one of them unmasks and attracts the attention of the dog, who rushes after him with such ardor that he fails to perceive that in the meantime the second thief has seized the sheep and dragged it into the wood. The dog finally renounces his pursuit of the fugitive and returns to his flock. Then the two confederates join each other and share the prey. In other circumstances it is a wolf who hunts with his female. When they wish to obtain possession of a deer, whose robust flight may last a long time, one of the couple, the male, for example, pursues him and directs his chase in such a way that the game must pass by a place where the female wolf is concealed. She then takes up the chase while the male reposes. It is an organized system of relays. The strength of the deer becomes necessarily exhausted; he can not resist the animation shown by his active foe, and is seized and killed. Then the other wolf calmly approaches the place of the feast to share his part of the booty.

The fox also successfully uses this method of coursing with relays.

It has often been repeated that man is the only creature sufficiently intelligent to utilize as weapons exterior objects like a stone or a brick; in a much greater degree, therefore, it was said, was he the only creature capable of striking from afar with a projectile. Nevertheless creatures so inferior as fish exhibit extreme skill in the art of reaching their prey at a distance. Several act in this way. There is first the Toxotes jaculator, who lives in the rivers of India. His principal food is formed by the insects who wander over the leaves of aquatic plants. To wait until they fell into the water would naturally result in but meagre fare. To leap at them with one bound is difficult, not to mention that the noise would cause them to flee. The Toxotes knows a better trick than that. He draws in some drops of water, and, contracting his mouth, projects them with so much force and certainty that they rarely fail to reach the chosen aim, and to bring into the water all the insects he desires. Other animals also squirt various liquids, sometimes in attack, but more especially in defence. The Cephalopods, for example, emit their ink, which darkens the water and allows them to flee. Certain insects exude bitter or fœtid liquids; but in all these cases, and in others that are similar, the animal finds in his own organism a secretion which happens to be more or less useful to his conservation. The method of the Toxotes is different. It is a foreign body which he takes up, and it is an intended victim at which he takes aim and which he strikes; his movements are admirably co-ordinated to obtain a precise effect.

Another fish, the Chelinous of Java, also acts in this manner. He generally lives in estuaries. It is, therefore, a brackish water which he takes up and projects by closing his gills and contracting his mouth; he can thus strike a fly at a distance of several feet. Usually he aims sufficiently well to strike it at the first blow, but sometimes he fails. Then he begins again until he has succeeded, which shows that his movements are not those of a machine. He knows what he is doing, what effect ought to be produced, and whether this desired result has happened, and he perseveres until the insect has fallen. These facts are unquestioned; the Chinese preserve these curious fish in jars, and amuse themselves by making them carry on this little exercise. Many observers have witnessed and described it.

THE DEATH-FEIGNING INSTINCT.—W. H. Hudson

MOST people are familiar with the phenomenon of "death-feigning," commonly seen in coleopterous insects and in many spiders. This highly curious instinct is also possessed by some vertebrates. In insects, it is probably due to temporary paralysis occasioned by sudden concussion, for when beetles alight abruptly, though voluntarily, they assume that appearance of death which lasts for a few moments. Some species, indeed, are so highly sensitive that the slightest touch, or even a sudden menace, will instantly throw them into this motionless, death-simulating condition. Curiously enough, the same causes which produce this trance in slow-moving species, like those of Scarabæus, for example, have a precisely contrary effect on species endowed with great activity. Rapacious beetles, when disturbed, scuttle quickly out of sight, and some water-beetles spin about the surface, in circles or zigzag lines, so rapidly as to confuse the eye. The common long-legged spiders (Pholcus) when approached draw their feet together in the middle of the web, and spin the body round with such velocity as to resemble a whirligig.

Certain mammals and birds also possess the death-simulating instinct, though it is hardly possible to believe that the action springs from the same immediate cause in vertebrates and in insects. In the latter, it appears to be a purely physical instinct, the direct result of an extraneous cause, and resembling the motions of a plant. In mammals and birds, it is evident that violent emotion, and not the rough handling experienced, is the final cause of the swoon.

Passing over venomous snakes, skunks, and a few other species in which the presence of danger excites only anger, fear has a powerful, and in some cases a disabling, effect on animals; and it is this paralyzing effect of fear on which the death-feigning instinct, found only in a few widely separated species, has probably been built up by the slow cumulative process of natural selection.

I have met with some curious instances of the paralyzing effect of fear. I was told by some hunters in an outlying district of the pampas of its effect on a jaguar they started, and which took refuge in a dense clump of dry reeds. Though they could see it, it was impossible to throw the lasso over its head, and after vainly trying to dislodge it, they at length set fire to the reeds. Still it refused to stir, but lay with head erect, fiercely glaring at them through the flames. Finally, it disappeared from sight in the black smoke; and when the fire had burned itself out, it was found, dead and charred, in the same spot.

On the pampas, the Gauchos frequently take the black-necked swan by frightening it. When the birds are feeding or resting on the grass, two or three men or boys on horseback go quietly to leeward of the flock, and, when opposite to it, suddenly wheel and charge it at full speed, uttering loud shouts, by which the birds are thrown into such terror that they are incapable of flying, and are quickly despatched.

I have also seen Gaucho boys catch the silver-bill (Lichenops perspicillata) by hurling a stick or stone at the bird, then rushing at it, when it sits perfectly still, disabled by fear, and allows itself to be taken. I myself once succeeded in taking a small bird of another species in the same way.

Among mammals, our common fox (Canis azaræ), and one of the opossums (Didelphys azaræ), are strangely subject to the death-simulating swoon. For it does indeed seem strange that animals so powerful, fierce and able to inflict such terrible injury with their teeth should also possess this safeguard, apparently more suited to weak inactive creatures that can not resist or escape from an enemy and to animals very low down in the scale of being. When a fox is caught in a trap or run down by dogs, he fights savagely at first, but by and by relaxes his efforts, drops on the ground and apparently yields up the ghost. The deception is so well carried out that dogs are constantly taken in by it, and no one, not well acquainted with this clever trickery of nature, but would at once pronounce the creature dead, and worthy of some praise for having perished in so brave a spirit.

Now, when in this condition of feigning death, I am sure that the animal does not altogether lose consciousness. It is exceedingly difficult to discover any evidence of life in the opossum; but when one withdraws a little way from the feigning fox, and watches him very attentively, a slight opening of the eye may be detected; and finally, when left to himself, he does not recover and start up like an animal that has been stunned, but slowly and cautiously raises his head first, and only gets up when his foes are at a safe distance. Yet I have seen Gauchos, who are very cruel to animals, practice the most barbarous experiments on a captive fox without being able to rouse it into exhibiting any sign of life. This has greatly puzzled me, since if death-feigning is simply a cunning habit, the animal could not suffer itself to be mutilated without wincing. I can only believe that the fox, though not insensible, as its behavior on being left to itself seems to prove, yet has its body thrown by extreme terror into that benumbed condition which simulates death, and during which it is unable to feel the tortures practiced upon it.

The swoon sometimes actually takes place before the animal has been touched, and even when the exciting cause is at a considerable distance. I was once riding with a Gaucho, when we saw, on the open level ground before us, a fox, not yet fully grown, standing still and watching our approach. All at once it dropped, and when we came up to the spot it was lying stretched out, with eyes closed, and apparently dead. Before passing on, my companion, who said it was not the first time he had seen such a thing, lashed it vigorously with his whip for some moments, but without producing the slightest effect.

The death-feigning instinct is possessed in a very marked degree by the spotted tinamou or common partridge of the pampas (Nothura maculosa). When captured, after a few violent struggles to escape, it drops its head, gasps two or three times, and, to all appearances, dies. If, when you have seen this, you release your hold, the eyes open instantly, and, with startling suddenness and a noise of wings, it is up and away and beyond your reach forever. Possibly, while your grasp is on the bird, it does actually become insensible, though its recovery from that condition is almost instantaneous. Birds when captured do sometimes die in the hand, purely from terror. The tinamou is excessively timid, and sometimes when birds of this species are chased—for

Gaucho boys frequently run them down on horseback—and when they find no burrows or thickets to escape into, they actually drop dead on the plain. Probably, when they feign death in their captor's hand, they are in reality very near to death.

BIRDS.—J. ARTHUR THOMSON

BIRDS are in some ways the highest of the vertebrate animals. They represent the climax of that passage from water to land which the backboned series illustrates. Their skeleton is more modified from the general type than that of mammals; their arrangements for locomotion, breathing, and nutrition are certainly not less perfect; their body temperature, higher than that of any other animals, is an index to the intense activity of their general life; their habitual and adaptive intelligence is familiarly great, while in range of emotion and sense impressions they must be allowed the palm. It is, in fact, only when we emphasize the development of the nervous system, and the closeness of connection between mother and offspring, that the mammals are seen to have a right to their pre-eminence over birds. Birds and mammals represent two divergent lines of progress, and stand in no close connection, but the affinities between birds and reptiles are sufficiently marked to warrant their being included in a common class (Sauropsida), in contrast to the amphibians and fishes (Ichthyopsida) on the one hand, and Mammalia on the other. Among the numerous points of difference which separate birds from their nearest relations, the reptiles, and from mammals, the following may be noticed:

	REPTILES	BIRDS	MAMMALS
Covering	Scales or scutes	Feathers	Hair
Number of fingers . .	Always more than three	At most three	Five or fewer
" " skull condyles	One	One	Two
Number of aortic arches	At least two	One, right	One, left
Diaphragm	Only incipient	Only incipient	Complete
Blood	Cold	Hottest	Warm
Position of optic lobes .	On top of brain	At sides of brain	Covered up
Parturition	Ovi- or viviparous	Oviparous	Except two viviparous

But those contrasts are only a few of the less technical selected from Professor Huxley's masterly comparison of the three classes. To appreciate the full extent of the resemblances and differences between birds and reptiles, and the contrast between both and mammals, the reader must consult Huxley's *Anatomy of Vertebrate Animals.*

Most birds use their wings in flight, the feather-covered arms being raised and depressed with great rapidity by means of the breast muscles. Every one who has watched birds is familiar with the marked differences in rapidity and mode of flight. It has been calculated that a common average of rapidity is about 40 to 60 feet per second, but records of the feats of carrier-pigeons, etc., certainly greatly surpass this. It seems probable that strong-winged birds, like eagles, can cover about 80 feet in a second. Buffon noted that they disappeared from sight in about three minutes. Strong birds, like the albatross and birds of prey, can not fly very rapidly, but can sustain their exertions for long periods, while many other birds rarely take prolonged flights, except during migration. The ostrich uses its wings to help it along in its rapid race; some aquatic birds, like the steamer-duck, use them as paddles, auxiliary to their legs. On the ground, birds vary greatly in rate and manner of progression: the swift strides of the ostrich, the rapid run of the partridge, the hopping of the sparrow are well-known illustrations of different gaits. That many birds are expert divers and climbers is also a familiar fact.

The great activity of birds is associated with very efficient respiration. Expiration, or the expulsion of used air, is managed by the contraction of breast and abdominal muscles, which compress the inclosed cavities and force the air from the sacs and lungs. When these muscles are relaxed the cavities again elastically expand, and fresh air rushes in by the windpipe to lungs and air sacs.

With few exceptions, birds have a vocal organ, and are able to produce more or less variable sounds. The organ is, however, wanting in the running birds, such as the ostrich and the American vultures. The sounds produced are almost as varied as the different kinds of birds, and an expert ornithologist has little difficulty in identifying a great number of forms by their distinctive noises. That some chirp and others scream, that chattering describes the language of many and croaking that of others, that some boom and others bark, that the crows caw, and the laughing jackass laughs, that the mocking-bird imitates, and the parrot becomes able to articulate, and above all that the lark trills and the nightingale truly sings, are well-known illustrations of the variety of bird language. The weird cry of the curlew or whaup, the melancholy voice of the sea-mew, the gabble of ducks, the crowing of the cock, the soft cooing of the dove, the hoarse voice of the corncrake, the ecstatic melody of the bobolink, the cheerful notes of the blackbird, the educated music of the canary, are again a random selection of instances from an almost infinite medley. It is among the so-called perchers, songsters, or Insessores that we find song really developed, and that for most part in the males, and in highest degree at breeding time. Though the notes are not musically pure, many songs of birds have been expressed in musical notation, and every one is familiar with imitations in word form. Singing is an unbidden expression of emotional energy. It is most marked at the high tide of sexual emotion during the breeding season. It is best, sometimes solely, developed in the males, who use their powers to attract the females, and often vie with one another in so doing. In other cases the note is obviously used as language, expressing alarm and the like, for that some birds are able by voice to convey impressions to one another is indubitable. In so far as the song is an instrument and expression of sexual attraction, it fails to be included among those powers which have been strengthened and developed by sexual selection.

After the strain of the reproductive period, or sometimes at the low ebb of mid-winter, the old feathers drop off, and birds undergo annual moult. The use of this in replacing breakage, and in furnishing a complete machinery for the flight of migration, is very evident; the cause is not yet sufficiently investigated. Moulting obviously presents some analogies with skin-casting and hair-shedding in other animals, and must be associated with some deep-seated constitutional change, such as its connection with the end of the breeding season suggests. Besides this annual growth of new feathers, many birds exhibit double and some triple moulting. The ptarmigan, for instance, changes its suit three times in the year, moulting after breeding into gray, changing this for white as the winter sets in, and acquiring in spring a third and most attractive set of feathers. In association with sexual attraction many male birds seem to undergo a partial moult, as the result of which they acquire those special decorations which are the index of a reproductive climax.

Birds usually pair in springtime, but to this rule there are many exceptions. Fertilization is internal, and all birds are oviparous. The number of eggs is often in inverse proportion to the size of the bird. Several, such as the apteryx, lay only one; the doves and birds of prey lay two or three, but the majority of birds many more.

It is important to notice that the higher development of birds, as compared with reptiles, is associated with the production of fewer offspring, but at the same time with the enormous increase of parental care and sacrifice. If the young are to be developed within the eggs, the latter must be kept at an approximately constant warmth. In almost all cases this is effected by brooding, the frequent helplessness of the young, the very common arboreal habit, the not infrequent enemies, have necessitated a most varied series of nest-building contrivances. The nest is built before the eggs are ready to be laid, and in most cases the female takes the prominent part in its construction. But both in the building and in the subsequent brooding the male may do his share, or in some cases much more. Each species usually has its own peculiar style and material of construction, though this may be adapted to varying conditions. The nests are usually solitary, more rarely grouped, and very exceptionally (as among cassowaries and ostriches) common property. Rooks, sea-fowl, herons, are familiar examples of breeding communities, while the sociable grosbeak, the republican swallows, and a few others, form even closer associations. The cuckoo and the cowbird have managed by a sort of parasitism to shirk their task, and quite a number of birds lay their eggs in an exceptional manner in the nests of neighbors. The beak is the organ most used in construction, but the pressure of the body may round off the forming nest, and the feet may also be used. How comfortable a nest may be made inside every one knows; how adroitly hidden it may be by external decorations of moss and lichen is familiar to every nest-hunter. The smaller birds usually build the more beautiful nests, and every variety occurs, from the comparatively careless hole in the sand made by the ostrich to the skilfully suspended and neatly fashioned nest of the tailor-bird. It must be noticed that habits vary considerably, as the very diverse nests built in different circumstances by falcon, eagle, heron, etc., well illustrate. Nests are shifted to suit food-supply, and vary in structure according to the available material. And again, since nest-building is obviously an acquired habit, which gradually rewarded the species in the greater success of both parent and offspring during breeding time, it is natural to find it dispensed with in many cases where the nature of the situation rendered no actual nest necessary, or where the birds for some other reason have never learned the habit. Some sea-birds, like the auk, simply lay on the rocky ledges of their haunts; some ground-birds simply deposit their eggs on the bare soil.

Burrowed holes are made by sand-martins, bee-eaters, penguins, kingfishers, and many others. The prairie-owl, living in the burrows of the prairie-dog and of the armadillo, is a well-known example of peculiar habit, and in the first case of curious partnership. Ground nests, generally of the simplest character, with rough and scanty accumulation of nest material, are made by swans, ducks, geese, fowls, gulls, waterhens, corncrakes, etc. Mud nests, constructed from damp earth, are well illustrated by the house-swallows, blue-creeper, flamingo, etc. The common singing thrush is well known to make a firm nest of clay and cow-dung mixed with moss. Carpenter-nests, formed with more or less preparation in the holes of trees, are used by woodpeckers and a few other arboreal birds. Platform nests, simply consisting of flat seats, are formed by the ring and turtle doves, by eagles, storks, and cranes. In some parts of the Continent the flat nests formed by the storks on the tops of buildings are familiar enough objects. Basket nests are such loosely interwoven constructions of grass, stems, twigs, etc., as are made by the crows, missel-thrushes, and most singing birds. The green weaving birds (Ploceus pensilis) hang their loosely woven nests, with downward directed opening, on the Madagascar trees. The South African republican birds (Philitærus socius) form hundreds of hanging nests on the branches, under the shelter of a common thatch. Woven nests are the more delicately constructed and really woven constructions of wool, hair, bark, grass, etc., which are made by such birds as the goldfinch, the Baltimore bird, and very many others. Sewed nests, composed of leaves sewed together by the beak as needle, are well illustrated by various species of Icterus, and by the Indian tailor-bird (Orthotomus bennetii). Felt-work nests are woven from the wool of plants or animals, sometimes with other material in addition; the humming-birds and the bullfinch form beautiful nests of this fashion. Cement nests are bound together by a viscid and very adhesive secretion, which is mixed with saliva, and used to glue the materials of the nest together. The nests of the American swallow, the edible birds' nests of the Salangani, sought after as luxuries by Chinese and others, are of this cemented type. Dome or moss nests are roofed in above and have an entrance on the side. The common wren, the water-wagtail, and the tits build on this principle. The beautiful bottle-shaped nest of the titmouse is one of the best examples. The parasite habit is well known among cuckoos and cowbirds. The nest of another bird is utilized to the future loss of the rightful inmates, and with obvious economy of labor on the part of the intruders. Thus sparrows usurp the nests of swallows, and starlings those of woodpeckers. Pheasant and partridge eggs are sometimes found in the same nest, and the same has been observed in many cases—*e. g.,* gull and eider-duck. When artificial nests are forthcoming, birds are glad to be relieved of the labor of construction, and different birds thus sometimes share a common box. The resorts of birds, when convenient nooks are available, are often extremely curious.

It is a well-known fact that comparatively few birds (at any rate outside of the tropics) remain in the same place all the year round. They do not hibernate, but migrate on the approach of cold. Some we know as winter visitors, returning north again in spring, most we know only in summer, for in autumn they fly to the warmer south; a third set we call "birds of passage"; for these we only know somewhat incidentally as they pass through on their way elsewhere.

Thus the swallow, the cuckoo, the nightingale, etc., come to Britain in summer and breed there, being winter residents further south; the fieldfare, jacksnipe, bean-goose, redwing, and some others, reach Great Britain in winter, being summer residents and breeders further north; while the little sandpipers are familiar examples of the true birds of passage which we know only for a short time as they rest on our shores in the journey south in autumn, and north again in spring. These three classes are obviously only different cases of one fact of migration. Almost all birds are in some degree migra-

Birds of all Climes

1, Crested Grebe (*Podiceps*); 2, Toucan; 3, Hoopœ; 4, Parrot (*Melopsittacus*); 5, Barn Owl; 6, Crested Penguin; 7, King Vulture; 8, Ruff (*Pavoucella*); 9, Horned Owl; 10, Wood Duck; 11, Kingfisher; 12, Capuchin Bird; 13, Grouse; 14, Spoonbill; 15, California Quail

tory. Those which breed in the equatorial regions are the chief exceptions, and even they pass from hill to valley and back again. Forms, too, which seem to be constant residents of a non-tropical country are in many cases known to exhibit a partial or a very local migration. This is true, for instance, of the common wren and the red grouse in the north of Scotland. All birds breed in the colder regions of their migration. Changes in food supply and the temperature are the most important conditions impelling them to shift their habitats. The general trend of migration is always, as indicated, toward the equator in autumn, from the equator in spring; but the investigations of the British Migration Committee have clearly shown that the courses often come to be circular. The flight is the more universal in a country the more marked the contrast between summer and winter. The annual migration from breeding areas too cold for winter residence and food supply to warmer subsistence areas can not be understood apart from the history of climates. When the European climate was more equable, it was virtually indifferent to the birds where they went. As it grew colder the birds had to fly further and further south every few winters. Migration has become an inherited habit, for they set about it before the impelling conditions are directly present. According to Wallace, natural selection has played an important part in confirming this habit. Many facts about migration are still utterly obscure. The power birds have of flying straight and of returning to the same locality is very marvelous. It must be remembered that a continuous tradition is sustained; those who have made the journey before guide the others. Doubtless they have memory for great landmarks. They fly across the shallower parts of the Mediterranean, where a chain of islands in this submerged tract long remained to guide them. The smaller birds usually keep nearer the ground; but it must not be forgotten that the flight is usually mostly accomplished by night. Birds generally meet in concourses, and migrate in flocks. Only a few fly alone. Sometimes the old males remain, while the others "flit." The return northward is more rapid, without young ones or weaklings. The males often return first.

As birds have a full active life, with considerable variety of function, in usually complex environment, since, as we have already noticed, their sense-organs and nervous systems are highly developed, considerable exhibition of intelligence is to be expected. They seem to have great vividness of sense impressions, to judge from their power of recalling old haunts and old friends. Birds often return to the same place season after season, and they have been known to recognize an owner after the lapse of years. Their quickness of ear and power of retention are evidenced by the power some possess of learning to repeat sounds, both words and tunes. Some have exhibited marked fondness for music, and the æsthetic tastes of the bower-bird excite deserved admiration. Much more is known in regard to their marvelous hereditary, general, and largely automatic reasonable habits or "instincts" than in regard to their power of individually adapting their conduct to novel circumstances. Their beautiful and adroit contrivances of nest-building are very familiar instances of the former, but many instances of the latter have been recorded.

As to feelings, it is hardly necessary to refer to their unexampled exhibition of sexual emotion in song and dance, parade, and display, or to the marvelous parental love and sacrifice expressed in their nest-building labors, in their prolonged incubation, and in their care for and courage in defending their brood. Subtler emotions of jealousy, both in connection with and altogether apart from sex, of affection for owners or associations, of sympathy for wounded or enfeebled fellows, are also not rarely exhibited. That a bird singing continuously for hours does not represent a rare height of emotion is not to be believed. It may be fairly said that the joyous song of the lark "at heaven's gate" is an eloquent expression of emotion only surpassed perhaps by human music.

MIMICRY.—David Robertson

IN ordinary language a person who can imitate the accent, manner of talking, and acting of another is said to be a good mimic. In biology, however, the term mimicry is used in a metaphorical sense, being applied to the resemblance which one species of animal or plant frequently shows to another. This resemblance is usually of a protective character. It is evident that if the resemblance which a defenceless species of animal often has to a species well furnished with natural offensive and defensive weapons were a mere freak of nature, no satisfactory and philosophical explanation of the phenomenon could be given.

Scientific investigators have to lay aside their wonder, and laboriously set about finding a solution to the most intricate and puzzling phenomena both in natural and physical science.

Mimicry was first used by Mr. W. H. Bates to denote the advantageous and generally protective resemblance assumed by one species of animal or plant to another.

It will be seen further on that the resemblance is not confined to one species of animal to another species of animal, and one species of plant to a plant of quite a distinct species, but that it also exists between animals and plants.

Mr. A. R. Wallace, who, by his most patient and skilful researches in the domain of animal life, has clearly defined and limited the term mimicry as applied in biology, says: "A certain species of plant or animal possesses some special means of defence from its enemies, such as a sting, a powerful and disagreeable odor, a nauseous taste, or a hard integument or covering. Some other species, inhabiting the same district or part of it, and not itself provided with the same means of defence, closely resembles the first species in all external points of form and color, though often very different in structure and unrelated in the biological order."

In South America there are certain butterflies, the Heliconidæ, which are remarkable for the variety and beauty of their colors; but they are incapable of rapid and sustained flight, and would for this reason fall an easy prey to insect-eating birds. Their wings, however, are never found among those rejected by insectivorous birds—in places where the remains of other butterflies frequently cover the ground. The Heliconidæ possess a powerfully disagreeable and pungent odor, which is so little volatile as to cling to the fingers for several days after handling one of these insects. Mr. Wallace inferred from this that they have a disagreeable taste, and would not on that account be eaten by birds. This was subsequently found by Mr. Belt to be the case.

Belonging to the family of the Pieridæ, which is quite distinct from the family of the Heliconidæ, and the greater number of which are white, there is a genus of small butterfly named Leptalis, which is eaten by birds. Some species of the genus Leptalis are white, like their allies among the Pieridæ, but the majority of the Leptales have an exact resemblance to some species of the Heliconidæ as far as regards the peculiar shape and color of their wings. The structure of the two families is completely different; in spite of this the resemblance is so strikingly close that both the experienced entomologists Mr. Bates and Mr. Wallace often at the time of capture mistook the one for the other, and only discovered their mistake by a closer examination. This has been looked upon as the most typical example of true mimicry, and is interesting from the fact that it is the first instance to which the term mimicry was applied.

It is necessary to distinguish carefully between true mimicry and several similar though superficial modes of resemblance which occur among organic beings. Several orchids resemble flies or spiders, but this is merely a case of accidental resemblance.

Among animals of a higher order than insects mimicry very seldom occurs.

Among mammals, all of which belong to the vertebrates, mimicry is seldom found, and it is supposed that only one genuine case has been observed.

Cladobates, an insect-eating genus found in the Malayan region, includes many species closely resembling squirrels both in size and color, as well in regard to the bushiness and position of the tail.

It is supposed by Mr. Wallace that Cladobates, owing to its resemblance to the harmless fruit-eating squirrel, may be enabled to approach insects and birds upon which it lives.

Cuckoos bear a considerable resemblance to hawks; the cuckoo tribe being weak and defenceless will in this way be enabled to elude the voracious hawks.

There is a genus of dull-colored birds in Australia and the Moluccas named Tropidorhynchus. These birds are large, active, and strong, with powerful claws and sharp beaks. They congregate in flocks, and are remarkably aggressive, driving away crows and even hawks.

In these same countries a genus of the group orioles lives, named Mimeta. These are much weaker than their allies the golden orioles, and besides are devoid of their brilliant colors, being usually olive-green or brown. It is a very common thing to find species of the Mimeta resembling Tropidorhynchi living on the same island.

The Tropidorhynchus bouruensis and Mimeta bouruensis are both found in the island of Bouru, the latter of which mimics the former as described by Mr. Wallace:

"The upper and under surfaces of the two birds are exactly of the same tints of dark and light brown. The Tropidorhynchus has a large, bare, black patch round the eyes; this is copied in the Mimeta by a patch of black feathers. The top of the head of the Tropidorhynchus has a scaly appearance from the narrow scaly-formed feathers, which are imitated by the broader feathers of the Mimeta, having a dusky line down each. The Tropidorhynchus has a pale ruff, formed of curious recurved feathers on the nape (which has given the whole genus the name of friar birds); this is represented in the Mimeta by a pale band in the same position. Lastly, the bill of the Tropidorhynchus is raised into a protuberant keel at the base, and that of the Mimeta has the same character, although it is not a common one in the genus." The result is that when superficially examined the birds seem to be identical, though possessed of important structural differences, and placed wide apart in any natural arrangement.

Mr. Wallace mentions some curious cases of mimicry among reptiles, where a venomous tropical genus of snakes, Elaps, belonging to America, is closely mimicked by several genera of harmless snakes.

It is in a special degree among insects that cases of mimicry are most frequently found.

Genuine cases of mimicry are not so easily shown to exist among plants. The resemblance between white dead nettle (Lamium album) and the stinging nettle, as well as between other labiates and the stinging nettle, may be considered to be a case of real mimicry as defined above.

The true stinging nettles are avoided by animals, owing to their possession of stinging hairs, which contain an acid fluid capable of causing pain and producing blisters.

It would be clearly of advantage to another plant to resemble one possessing such defensive armor as the stinging nettle.

There is another labiate, Ajuga ophrydis of South Africa, mentioned by Mr. Mansel Weale. This labiate closely resembles an orchid, and for this reason insects may be induced to visit the flower and thus fertilize it.

Mr. Worthington Smith, the eminent fungologist, has found three rare British fungi, each accompanying common species, which they closely resembled; and one of the common species has a bitter nauseous taste. In this case we have an example of genuine mimicry.

Dr. Hans Meyer has given in his valuable work, *Across East African Glaciers,* some very striking instances of mimicry. He says:

"The similarity for the purpose of protection of the majority of the great mammals, *i. e.,* the likeness of the color of their coats, and partly also of their external appearance, to the features and colors of the regions which they inhabit, must strike every traveler with astonishment.

"At a small distance the hartbeest (antelope), when stationary, is really not distinguishable from red ant-heaps which everywhere abound; the long-legged and long-necked giraffe can not be distinguished from the dead trunk of a mimosa, the zebra from a gray-brown clump of grass and thorn-scrub, the rhinoceros from a fallen trunk of a tree. It is only when they move that they can be distinguished. Nature has also extended this protective mimicry (Schutzspiel) to the small insects; and perhaps for this reason they often escape the eye specially in search of them; for butterflies and grasshoppers look like dry twigs, the cicadæ like leaf-stalks, the spiders like thorns, the phasmodæ like bare twigs, beetles like small lumps of earth and small stones, moths like mosses and lichens.

"This protective mimicry is manifested not only in regard to the colors and forms of the animals, but also as regards their movements, or their manner of standing still, and in their preference for certain localities appropriate to their disguise. There is protection everywhere; protection against climatic extremes and against animal foes; such varied and abundant protection as could only be developed by natural selection in a primeval continent like Africa."

In spite of the voluminous literature of "animal mimicry" since Bates first published his classical memoir on the subject, the exact nature of the process whereby insects and other creatures "mimic" (though that is not the appropriate word) the appearance of other species is still far from being understood. All we know is that this power, this resemblance of a beetle or a butterfly to the ground upon which it sits, the sticks among which it creeps, or the leaves among which it flutters, helps to save it from destruction, while it is a decided advantage to it to "mimic" another insect which is sedulously avoided by birds. The observations in this byway of zoology are as curious as any yet made. It is found, for instance, that an American spider (Cyrlarachne) takes the semblance of a little land shell very abundant in the localities which it frequents; and that another species (Thomisus alcatorius), remarkable for the length of its forelegs, so fastens itself on the stems of grasses as to be nearly indistinguishable from the spikelets.

Some observations, for which we are indebted to M. Heckel of Marseilles, throw a good deal of light on the origin of mimicry, at least so far as the assumption of protective coloration is concerned. There is a spider (Thomisus onustus) very common in the south of France which conceals itself in the flower of a species of wild convolvulus for the purpose of trapping two kinds of fly on which it feeds. This convolvulus is found in three principal varieties: white, pink with deeper spots of the same hue, and light pink forms with a slight greenishness on the external wall of the flower. Each of these three varieties is visited by the spider. But the varieties of spider conform in hue to the varieties of the flower, and each confines itself to the one which is most protective to it. If, however, the animal is confined to a Dahlia versicolor, it conforms to the hue of its new abode—that is, the pink one turns to red, and, in like manner, if transferred to the yellow snapdragon, it takes the color of this flower. They change in shade as the shade of their host changes, and when pink, white, green, and yellow varieties are confined together in a box they all become nearly white.

The question of protective coloration in fishes has of late received some light which compels a revision of our former theories on the subject. It has usually been held that the color of fishes is of the mimicry order—that is, it has been acquired for the purpose of deceiving their enemies. Trout will very commonly take the hue of the river bottom over which they swim, and, as every one knows, it is difficult to detect a flounder or other flat fish at rest, though when it turns over the white under surface of its body instantly reveals the creature's presence. The hue of the upper surface is due to the action of light. For when a sole was kept in a raised glass case, with light directed upward from below, pigment formed on the white side, and began to be absorbed on the one hitherto exposed to the same agent.

DWELLINGS.—Frédéric Houssay

ANIMALS construct dwellings either to protect themselves from the cold, heat, rain, and other chances of the weather, or to retire to at moments when the search for food does not compel them to be outside and exposed to the attacks of enemies. Some inhabit these refuges permanently; others only remain there during the winter; others, again, who live during the rest of the year in the open air, set up dwellings to bring forth their young, or to lay their eggs and rear the offspring.

We shall find every stage, from that of beings provided for by nature, and endowed with a special organ which secretes for them a shelter, up to those who are constrained by necessity to seek in their own intelligence an expedient to repair the forgetfulness of nature.

Nearly all the Mollusca are enveloped by a very hard calcareous case, secreted by their mantle: this shell, which is a movable house, they bear about with them and retire into at the slightest warning.

Caterpillars which are about to be transformed into chrysalides weave a cocoon, a very close dwelling in which they can go through their metamorphosis far from exterior troubles. It is an organic form of dwelling, or produced by an organ. It is not necessary to multiply examples of this kind; they are extremely numerous. In the same category must be ranged the cells issuing from the wax-glands which supply bees with materials for their combs in which they inclose the eggs of the queen with a provision of honey.

I do not wish to insist on creations of this kind which are independent of the animal's will and reflection. Near these facts must be placed those in which animals, still using a natural secretion, yet endeavor to obtain ingenious advantages from it unknown by related species.

There is, for example, the Macropus viridi-auratus, or paradise-fish, which blows air bubbles in the mucus produced from its mouth. This mucus becomes fairly resistant, and all the bubbles imprisoned and sticking side by side at last form a floor. It is beneath this floating shelter that the fish suspends its eggs for its little ones to undergo their early development.

Certain tubicolar annelids, whose skin furnishes abundant mucus which does not become sufficiently hard to form an efficacious protection, utilize it to weld together and unite around them neighboring substances, grains of sand, fragments of shell, etc. They thus construct a case which both resembles formations by special organs and manufacture by the aid of foreign materials. The larvæ of Phryganea, who lead an aquatic life, use this method to separate themselves from the world and prepare tubes in which to dwell. All the fragments carried down by the stream are good for their labors on condition only that they are denser than the water. They take possession of fragments of aquatic leaves, and little fragments of wood which have been sufficiently long in the water to have thoroughly imbibed it, and so become heavy enough to keep themselves at the bottom, or at least to prevent them from floating to the surface. It is the larva of Phryganea striata which has been best studied; those of neighboring species evidently act much in the same way, with differences only in detail. The little carpenter stops a fragment rather longer than his own body, lies on it and brings it in contact with other pieces along his own sides. He thus obtains the skeleton of a cylinder. The largest holes are filled up with detritus of all kinds. Then these materials are agglutinated by a special secretion. The larva overlays the interior of its tube with a covering of soft silk which renders the cylinder water-tight and consolidates the earlier labors. The insect is thus in possession of a safe retreat. Resembling some piece of rubbish, it completes its metamorphosis in peace, undisturbed by the carnivora of the stream.

Between the beings whom nature has endowed with a shelter and those who construct it by their own industry, we may intercept those who, deprived of a natural asylum and not having the inclination or the power to make one, utilize the dwellings of others, either when the latter still inhabit them, or when they are empty on account of the death or departure of the owner. In the interior of the branchial chamber of many bivalvular mollusca, and especially the mussel, there lives a little crustaceous commensal called the pea-crab (Pinnoteres pisum). He goes, comes, hunts, and retires at the least alarm within his host's shell. The mussel, as the price of its hospitality, no doubt profits by the prizes which fall to the little crab's claws. It is even said that the crab in recognition of the benefits bestowed by his indolent friend keeps him acquainted with what is passing on around, and as he is much more active and alert than his companion he sees danger much further away, and gives notice of it, asking for the door to be shut by lightly pinching the mussel's gill.

For birds like the cuckoo and the Molothrus it is not possible to plead extenuating circumstances. They occupy a place in an inhabited house without paying any sort of rent. Every one knows the cuckoo's audacity. The female lays her eggs in different nests and troubles herself no further about their fate. She seeks for her offspring a shelter which she does not take the trouble to construct, and moreover at the same time assures for them the care of a stranger in place of her own.

In North America a kind of starling, the Molothrus pecoris, commonly called the cowbird, acts in the same careless fashion. It lives in the midst of herds, and owes its specific name to this custom; it feeds on the parasites on the skin of cattle. This bird constructs no nest. At the moment of laying the female seeks out an inhabited dwelling, and when the owner is absent she furtively lays an egg there. The young intruder breaks his shell after four days' incubation, that is to say, usually much before the legitimate children; and the parents, in order to silence the beak of the stranger who, without shame, claims his share with loud cries, neglect their own brood which have not yet appeared, and which they abandon.

The habits of the Molothrus bovariensis, a closely allied Argentine cowbird, have been carefully studied by Mr. W. H. Hudson, who has also some interesting remarks as to the vestiges of the nesting instinct in this interesting parasitical bird, which is constantly dropping eggs in all sorts of places, even on the ground, most of them being lost. Mr. Hudson suggests that this bird lost the nest-making instinct by acquiring the semi-parasitical habit, common to many South American birds, of breeding in the large covered nests of the Dendrocolaptidæ, although, owing to increased severity in the struggle for the possession of such nests, this habit was defeated.

The Rhodius anarus, a fish of European rivers, also ensures a quiet retreat for his offspring by a method which is not less indiscreet. At the period of spawning, a male chooses a female companion and with great vigilance keeps off all those who wish to approach her. When the laying becomes imminent, the Rhodius, swimming up and down at the bottom of the stream, at length discovers a Unio. The bivalve is asleep with his shell ajar, not suspecting the plot which is being formed against him. It is a question of nothing less than of transforming him into furnished lodgings. The female fish bears underneath her tail a prolongation of the oviduct; she introduces it delicately between the mollusk's valves and allows an egg to fall between his branchial folds. In his turn the male approaches, shakes himself over it, and fertilizes it. Then the couple depart in search of another Unio, to whom to confide another representative of the race. The egg, well sheltered against dangers from without, undergoes development, and one fine day the little fish emerges and frisks away from his peaceful retreat.

The hermit-crab perhaps knows best how to take advantage of old clothes. He collects shells of Gasteropods, abandoned flotsam, the first inhabitant of which has died. The hermit-crab (Pagurus Bernhardus) is a Decapod Crustacean—that is to say, he resembles a very small crab. But his inveterate habit during so many generations of sheltering his abdomen in a shell prevents this part from being incrusted with lime and becoming hard. The legs and the head remain in the ordinary condition outside the house, and the animal moves bearing it everywhere with him; on the least warning he retires into it entirely. But the crustacean grows. When young he had chosen a small shell. A mollusk, in growing, makes his house grow with him. The hermit-crab can not do this, and when his dwelling has become too narrow he abandons it for one that is more comfortable. At first inclosed in the remains of a Trochus, he changes into that of a Purpura; a little later he seeks asylum in a whelk. Besides the shelter which these shells assure to the crustacean, they serve to mask his ferocity, and the prey, which approaches confidently what it takes to be an inoffensive mollusk, becomes his victim.

The great horned owl likewise does not construct a nest, but takes possession of the dwellings abandoned by others. These birds utilize for laying their eggs sometimes the nest of a crow or a dove, sometimes the lair which a squirrel had considered too dilapidated. The female, without troubling about the bad state of these ruins, or taking pains to repair them, lays her eggs here and sits on them.

It is time to turn to animals who have more regard for comfort, and who erect dwellings for themselves or their offspring. These dwellings may be divided into three groups: (1) Those which are hollowed in earth or in wood; (2) those which in the simplest form result from the division of material of any kind; then, as a complication, of materials bound together; then, as a last refinement, of delicate materials, such as blades of grass or threads of wool woven together; such are the nests of certain birds and the tents of nomads; (3) those which are built of moist earth which becomes hard on drying; the perfection of this method consists of piling up hard fragments, pieces of wood or ashlar, the moist earth being only a mortar which unites the hard parts together. Animals exercise with varying success these different methods, all of which man still practices.

We will first occupy ourselves with the dwelling hollowed in the earth. It is the least complicated form. The number of creatures who purely and simply bury themselves thus to obtain shelter is incalculable; I will only mention a few examples, and pass on from simple combinations to the more perfected industries, of which they present the first sketch.

Speaking generally, birds are accomplished architects. Certain of them are, however, content with a rudimentary cavern. There is no question here of those who retire to clefts in the rock or in trunks of trees, for in these cases the cavity is only the support of the true house, and it is in the construction of this that the artist reveals his talent. I wish to speak of animals which remain in a burrow without making a nest there. A paroquet of New Zealand called the kakapo (Strigops habroptilus) thus dwells in natural or hollowed excavations. It is only found in a restricted portion of the island and leads a miserable life there, habitually staying in the earth and pursued by numerous enemies, especially half-wild dogs. It tries to hold its own, but its wings and beak do not suffice to protect it, and the race would have completely disappeared if these birds were not able to resist, owing to the prudence with which they stay within their dwellings. They profit by a natural retreat, or one constructed in rocks or beneath roots of trees; they only come out when impelled by hunger, and return as soon as they can in case of danger.

A large number of animals also hollow out shelters for their eggs, with the double object of maintaining them at a constant temperature and of concealing them. Most reptiles act in this manner.

It is not only land animals which adopt this custom of living in the earth, and there sheltering their offspring. Fish also make retreats on the bank or at the bottom. To mention only one case, the bullhead (Cottus gobio) of English rivers, which spawns in the Seine in May, June, and July, acts in this manner. Beneath a rock in the sand it prepares a cavity; then seeks females and brings them to lay eggs in its little lodging. During the four or five weeks before they come out it watches the eggs, keeping away as far as possible every danger which threatens them. It only leaves its position when pressed by hunger, and as soon as the hunt is concluded, returns to the post of duty.

Other animals when digging have a double object: they wish to shelter themselves, and at the same time to find the water which they need for themselves or for the development of their young.

It is well known that frogs and toads generally go in the spring to lay their eggs in streams and ponds. A batrachian of Brazil and the hot regions of South America, the Cystignathus ocellatus, no doubt fearing too many dangers for the spawn if deposited in the open water, employs the artifice of hollowing, not far from the bank, a hole the bottom of which is filled by infiltration. It there places its eggs, and the little ones on their birth can lead an aquatic life while being guaranteed against its risks.

Many beings live permanently in a burrow; reptiles—snakes or lizards—are to be placed among these. Among others, the Lacerta stirpium arranges a narrow and deep hole, well hidden beneath a thicket, and retires into it for the winter, when cold renders it incapable of movement and at the mercy of its enemies. Before giving itself up to its hibernal sleep, it is careful to close hermetically the opening of the dwelling with a little earth and dried leaves. When spring returns and the heat awakens the reptile, it comes out to warm itself and to hunt, but never abandons its dwelling, always retiring into it in case of alarm and to pass there cold days and nights.

Darwin has observed and described how a little lacertilian, the Conlophus subcristatus, conducts its work of mining and digging. It establishes its burrow in a soft tufa, and directs it almost horizontally, hollowing it out in such a way that the axis of the hole makes a very small angle with the soil. This reptile does not foolishly expend its strength in this troublesome labor. It only works with one side of its body at a time, allowing the other side to rest.

For instance, the right anterior leg sets to work digging, while the posterior leg on the same side throws out the earth. When fatigued, the left legs come into play, allowing the others to repose.

Other animals, without building their cavern with remarkable skill, show much sagacity in the choice of a site calculated to obtain certain determined advantages. In Egypt there are dogs which have become wild. Having shaken off the yoke of man, which in the East affords them little or no support, they lead an independent life. During the day they remain quiescent in desert spots or ruins, and at night they prowl about like jackals, hunting living prey or feeding on abandoned carcasses. There are hills which have in a manner become the property of these animals. They have founded villages there, and allow no one to approach. These hills have an orientation from north to south, so that one slope is exposed to the sun from morning to midday and the other from midday to evening. Now, dogs have a great horror of heat. They fear the torrid heat of the south as much as in our climate they like to lie warmed by gentle rays; there is no shadow too deep for their siesta. Therefore, on these Egyptian hills every dog hollows out a lair on both slopes. In the morning, when he returns from his nocturnal expeditions, the animal takes refuge in the second, and remains there until midday, sunk in refreshing sleep. At that hour the sun begins to reach him, and to escape it he passes over to the opposite slope; it is a curious sight to see them all, with pendent heads and sleepy air, advance with trailing steps to their eastern retreat, settle down in it, and continue their dream and their digestion till evening, when they again set forth to prowl.

The trap-door spiders of the south of Europe construct burrows which have been studied with great care and in much detail by Moggridge. He found that there were four chief types of burrow. The whole burrow as well as the door are lined with silk, which also forms the hinge. The great art of the trap-door spider lies in her skilful forming of the door, which fits tightly, although it opens widely when she emerges, and which she frequently holds down when an intruder strives to enter, and in the manner with which the presence of the door is concealed, so as to harmonize with surrounding objects. Perhaps in no case is the concealment more complete than when dead leaves are employed to cover the door. In some cases a single withered olive leaf is selected, and it serves to cover the entrance; in other cases several are woven together with bits of wood or roots.

The trap-door spider (Mybale henzii, Girard), which is widely diffused in California, forms a simple shaft-like burrow, but, like the European trap-door spider, it is very skilful in forming an entrance and in concealing its presence. Its habits have lately been described by D. Cleveland of San Diego. In the adobe land hillocks are numerous; they are about a foot in height, and some three or four feet in diameter. These hillocks are selected by the spiders—apparently because they afford excellent drainage, and can not be washed away by the winter rains—and their stony summits are often full of spiders' nests. These subterranean dwellings are shafts sunk vertically in the earth, except where some stony obstruction compels the miner to deflect from a downward course. The shafts are from five to twelve inches in depth, and from one-half to one and a half inches in diameter, depending largely upon the age and size of the spider.

When the spider has decided upon a location, which is always in clay, adobe or stiff soil, he excavates the shaft by means of the sharp horns at the end of his mandibles, which are his pick and shovel and mining tools. The earth is held between the mandibles and carried to the surface. When the shaft is of the required size, the spider smoothes and glazes the wall with a fluid which is secreted by itself. Then the whole shaft is covered with a silken paper lining, spun from the animal's spinnerets.

The door at the top of the shaft is made of several alternate layers of silk and earth, and is supplied with an elastic and ingenious hinge, and fits closely in a groove around the rim of the tube. This door simulates the surface on which it lies, and is distinguishable from it only by a careful scrutiny. The clever spider even glues earth and bits of small plants on the upper side of his trap-door, thus making it closely resemble the surrounding surface.

The spider generally stations itself at the bottom of the tube. When, by tapping on the door, or by other means, a gentle vibration is caused, the spider runs to the top of his nest, raises the lid, looks out and reconnoitres. If a small creature is seen, it is seized and devoured. If the invader is more formidable, the door is quickly closed, seized and held down by the spider, so that much force is required to lever it open. Then, with the intruder looking down upon him, the spider drops to the bottom of his shaft.

It has been found by many experiments that when the door of his nest is removed, the spider can renew it five times—never more than that. Within these limitations, the door torn off in the evening was found replaced by a new one in the morning. Each successive renewal showed, however, a greater proportion of earth, and a smaller proportion of silk, until finally the fifth door had barely enough silk to hold the earth together. The sixth attempt, if made, was a failure, because the spinnerets had exhausted their supply of the web fluid. When the poor persecuted spider finds his domicile thus open and defenceless, he is compelled to leave it, and wait until his stock of web fluid is renewed.

Skilful diggers prepare burrows with several entrances; some even arrange several rooms, each for a special object. The otter seeks its food in the water, and actively hunts fish in ponds and rivers. But when fishing is over, it likes to keep dry and at the same time sheltered from terrestrial enemies. Its dwelling must also present an easy opening into the water. In order to fulfil all the conditions, its house consists first of a large room hollowed in the bank at a level sufficiently high to be beyond reach of floods. From the bottom of this keep a passage starts which sinks and opens about fifty centimetres beneath the surface of the water. It is through here that the otter noiselessly glides to find himself in the midst of his hunting domain without having been seen or been obliged to make a noisy plunge which would put the game to flight. If this were all, the hermetically closed dwelling would soon become uninhabitable, as there would be no provision for renewing the air, so the otter proceeds to form a second passage from the ceiling of the room to the ground, thus forming a ventilation tube. In order that this may not prove a cause of danger, it is always made to open up in the midst of brushwood or in a tuft of rushes and reeds.

Marmots also are not afraid of the work which will assure them a warm and safe refuge in the regions they inhabit, where the climate is rough. In summer they ascend the Alps to a height of 2,500 to 3,000 metres and rapidly hollow a burrow like that for winter time, which I am about to describe, but smaller and less comfortable. They retire into it during bad weather or to pass the night. When the snow chases them away and causes them to descend to a lower zone, they think about constructing a genuine house in which to shut themselves during the winter and to sleep. Twelve or fifteen of these little animals unite their efforts to make first a horizontal passage, which may reach the length of three or four metres. They enlarge the extremity of it into a vaulted and circular room more than two metres in diameter. They make there a good pile of very dry hay on which they all install themselves, after having carefully protected themselves against the external cold by closing up the passage with stones and calking the interstices with grass and moss.

In solitary woods or roads the badger (Meles), who does not like noise, prepares for himself a peaceful retreat, clean and well ventilated, composed of a vast chamber situated about a metre and a half beneath the surface. He spares no pains over it, and makes it communicate with the external world by seven or eight very long passages, so that the points where they open are about thirty paces distant from one another. In this way, if an enemy discovers one of them and introduces himself into the badger's home, the badger can still take flight through one of the other passages. In ordinary times they serve for the aeration of the central room. The animal attaches considerable importance to this. He is also very clean in his habits, and every day may be seen coming out for little walks, having an object of an opposite nature to the search for food. This praiseworthy habit is, as we shall see, exploited by the fox in an unworthy manner.

The fox has many misdeeds on his conscience, but his conduct toward the badger is peculiarly indelicate. The fox is a skilful digger, and when he can not avoid it, he can hollow out a house with several rooms. The dwelling has numerous openings, both as a measure of prudence and of hygiene, for this arrangement enables the air to be renewed. He prepares several chambers side by side, one of which he uses for observation and to take his siesta in; a second as a sort of larder in which he piles up what he can not devour at once; a third in which the female brings forth and rears her young. But he does not hesitate to avoid this labor when possible. If he finds a rabbit warren he tries first to eat the inhabitants, and then, his mind cleared from this anxiety, arranges their domicile to his own taste, and comfortably installs himself in it. In South America, again, the Argentine fox frequently takes up permanent residence in a vizcachera, ejecting the rightful owners; he is so quiet and unassuming in his manners that the vizcachas become indifferent to his presence, but in spring the female fox will seize on the young vizcachas to feed her own young, and if she has eight or nine, the young of the whole village of vizcachas may be exterminated.

The badger's dwelling appears to the fox particularly enviable. In order to dislodge the proprietor he adopts the following plan: Knowing that the latter can tolerate no ordure near his home, he chooses as a place of retirement one of the passages which lead to the chamber of the peaceful recluse. He insists repeatedly, until at last the badger, insulted by this grossness, and suffocated by the odor, decides to move elsewhere and hollow a fresh palace. The fox is only waiting for this, and installs himself.

The vizcacha (Lagostomus trichodactylus) is a large rodent inhabiting a vast extent of country in the pampas of La Plata, Patagonia, etc. Unlike most other burrowing species, the vizcacha prefers to work on open level spots. On the great grassy plains it is even able to make its own conditions, like the beaver, and is in this respect, and in its highly developed social instinct, among the two or three mammals which approach man, although only a rodent, and even in this order, according to Waterhouse, coming very low down by reason of its marsupial affinities.

The vizcacha lives in small communities of from twenty to thirty members, in a village of deep-chambered burrows, some twelve or fifteen in number, with large pit-like entrances closely grouped together, and as the vizcachera, as this village is called, endures for an indefinitely long period, the earth which is constantly brought up forms an irregular mound thirty or forty feet in diameter, and from fifteen to thirty inches above the level of the road; this mound serves to protect the dwelling from floods on low ground. A clearing is made all round the abode and all rubbish thrown on the mound; the vizcachas thus have a smooth turf on which to disport themselves, and are freed from the danger of lurking enemies.

The entire village occupies an area of one hundred to two hundred square feet of ground. The burrows vary greatly in extent; usually in a vizcachera there are several that, at a distance of from four to six feet from the entrance, open into large circular chambers. From these chambers other burrows diverge in all directions, some running horizontally, others obliquely downward to a maximum depth of six feet from the surface; some of these galleries communicate with those of other burrows.

On viewing a vizcachera closely, the first thing that strikes the observer is the enormous size of the entrances to the central burrows in the mound; there are usually several smaller outside burrows. The entrance to some of the principal burrows is sometimes four to six feet across the mouth, and sometimes it is deep enough for a tall man to stand in up to the waist.

Certain rodents have carried hollow dwellings to great perfection. Among these the hamster of Germany (Cricteus frumentarius) is not the least ingenious. To his dwelling-room he adds three or four storehouses for amassed provisions. The burrow possesses two openings: one, which the animal prefers to use, which sinks vertically into the soil; the other, the passage of exit, with a gentle and very winding slope. The bottom of the central room is carpeted with moss and straw, which make it a warm and pleasant home. A third tunnel starts from this sleeping chamber, soon forking and leading to the wheat barns. Thus during the winter the hamster has no pressing need to go out except on fine days for a little fresh air. He has everything within his reach, and can remain shut up with nothing to fear from the severity of the season.

It is not only the soil which may serve for retreat; wood serves as an asylum for numerous animals, who bore it, and find in it both food and shelter. In this class must be placed a large number of worms, insects, and crustaceans. One of these last, the Chelura terebrans, a little amphipod, constitutes a great danger for the works of man. It attacks piles sunken to support structures, and undermines them to such a degree that they eventually fall.

An insect, the Xylocopa violacea, related to the humblebee, from which it differs in several anatomical characters, and by the dark violet tint of its wings, brings an improvement to the formation of the shelter which it makes in wood for its larvæ. Instead of hollowing a mere retreat to place there all its eggs indiscriminately, it divides them into compartments, separated by horizontal partitions. It is the female alone who accomplishes this task, connected with the function of perpetuating the race. She chooses an old tree-trunk, a pole, or the post of a fence, exposed to the sun and already worm-eaten, so that her labor may be lightened. She first attacks the wood perpendicularly to the surface, then suddenly turns and directs downward the passage, the diameter of which is about equal to the size of the insect's body. The Xylocopa thus forms a tube about thirty centimetres in length. Quite at the bottom she places the first egg, leaving beside it a provision of honey necessary to nourish the larva during its evolution; she then closes it with a partition. This partition is made with fragments of the powder of wood glued together with saliva. A first horizontal ring is applied round the circumference of the tube; then in the interior of this first ring a second is formed, and so on continuously, until the central opening, more and more reduced, is at last entirely closed up. This ceiling forms the floor for the next chamber, in which the female deposits a new egg, provided, like the other, with abundant provisions. The same acts are repeated until the retreat becomes transformed into a series of isolated cells in which the larvæ can effect their development, and from which they will emerge either by themselves perforating a thin wall which separates them from daylight, or by an opening which the careful mother has left to allow them to attain liberty without trouble.

The second class of habitation, which I have called the woven dwelling, proceeds at first from the parceling up of substances, then of objects capable of being entangled like wisps of wood or straw, then of fine and supple materials which the artisan can work together in a regular manner, that is to say, by felting or weaving.

There are, first, cases in which the will of the animal does not intervene, or at least is very slightly manifested. The creature is found covered and protected by foreign bodies which are often living beings. Spider-crabs (Maïa), for example, have their carapaces covered with algæ and hydroids of all sorts. Thus garnished, the Crustaceans have the advantage of not being recognized from afar when they go hunting, since beneath this fleece they resemble some rock. H. Fol has observed at Villefranche-sur-Mer a Maïa so buried beneath this vegetation that it was impossible at first sight to distinguish it from the stones around. Under these conditions the animal submits to a shelter rather than creates it. Yet it is not so passive as one might at first be led to suppose. When the algæ which flourish on its back become too long and impede or delay its progress, it tears them off with its claws and thoroughly cleans itself. The carapace being quite clean, the animal finds itself too smooth and too easy to distinguish from surrounding objects; it therefore takes up again fragments of algæ and replaces them where they do not delay to take root like cuttings and to flourish anew.

The sponge-crab (Dromia vulgaris) also practices this method of shelter. It seizes a large sponge and maintains it firmly over its carapace with the help of the posterior pair of limbs. The sponge continues to prosper and to spread over the Crustacean who has adopted it. The two beings do not seem to be definitely fixed to each other; the contact of a sudden wave will separate them. When the divorce is effected, the Dromia immediately throws itself on its cherished covering and replaces it. M. Künckel d'Herculais tells of one of these curious Crustaceans which delighted the workers in the laboratory of Concarneau. The need for covering themselves experienced by these crabs is so strong that in aquariums when their sponge is taken away they will apply to the back a fragment of wrack or of anything which comes to hand. A little white cloak with the arms of Brittany was manufactured for one of these captives, and it was very amusing to see him put on his overcoat when he had nothing else wherewith to cover himself.

An Australian bird, the Catheturus Lathami, as described by Gould, is still in the rudiments, and limits itself to preparing an enormous pile of leaves. It begins its work some weeks before laying its eggs; with its claws it pushes behind it all the dead leaves which fall on the earth and brings them into a heap. The bird throws new material on the summit until the whole is of suitable height. This detritus ferments when left to itself, and a gentle heat is developed in the centre of the edifice. The Cathe-turus returns to lay near this coarse shelter; it then takes each egg and buries it in the heap, the larger end uppermost. It places a new layer above, and quits its labor for good. Incubation takes place favored by the uniform heat of this decomposing mass, hatching is produced, and the young emerge from their primitive nest.

Birds are not alone in constructing temporary dwellings in which to lay their eggs; some fish are equally artistic in this kind of industry, and even certain reptiles. The alligator of the Mississippi would not perhaps at first be regarded as a model of maternal foresight. Yet the female constructs a genuine nest. She seeks a very inaccessible spot in the midst of brushwood and thickets of reeds. With her jaw she carries thither boughs which she arranges on the soil and covers with leaves. She lays her eggs and conceals them with care beneath vegetable re-mains. Not yet considering her work completed, she stays in the neighborhood watching with jealous eye the thicket which shelters the dear deposit, and never ceases to mount guard threateningly until the day when her young ones can follow her into the stream.

A hymenopterous relative of the bees, the Mega-chile, cuts out in rose-leaves fragments of appro-priate form which it bears away to a small hole in a tree, an abandoned mouse nest or some similar cavity.

There it rolls them, works them up, and arranges them with much art, so as to manufacture what resemble thimbles, which it fills with honey and in which it lays.

The Anthocopa acts in a similar manner, carpeting the holes of which it takes possession with the delicate petals of the corn poppy.

The retreats of nocturnal birds of prey do not differ in method of construction from these two kinds of nests. They are holes in trees, in ruins, in old walls, and are lined with soft and warm material. These dwellings are related, not to the type of the hollowed cave, but to that of the habitation manufactured from mingled materials. They constitute an inferior form in which the pieces are not firmly bound together, but need support throughout. The cavity is the support which sustains the real house.

Diurnal birds of prey are the first animals who practice skilfully the twining of materials. Their nests, which have received the name of eyries, are not yet masterpieces of architecture, and reveal the beginning of the industry which is pushed so far by other birds. Usually situated in wild and inaccessible spots, the young are there in safety when their parents are away on distant expeditions. The abrupt summits of cliffs and the tops of the highest forest trees are the favorite spots chosen by the great birds of prey. The eyrie generally consists of a mass of dry branches which cross and mutually support one another, constituting a whole which is fairly resistant.

The abodes of squirrels, though exhibiting more art, are constructions of the same nature; that is to say, they are formed of interlaced sticks. This animal builds its home to shelter itself there in the bad season, to pass the night in, and to rear its young. Very agile, and not afraid of climbing, it places its domicile near the tops of our highest forest trees. Rather capricious also, and desiring change of residence from time to time, it builds several of them; at least three or four, sometimes more. The materials which it needs are collected on the earth among fallen dead branches, or are torn away from the old abandoned nest of a crow or some other bird. The squirrel first builds a rather hollow floor by intermingling the fragments of wood which it has brought. In this state its dwelling resembles a magpie's nest. But the fastidious little animal wishes to be better protected and not thus to sleep in the open air. Over this foundation he raises a conical roof; the sticks which form it are very skilfully disposed, and so well interlaced that the whole is impenetrable to rain. The house must still be furnished, and this is done with Oriental luxury; that is to say, the entire furniture consists of a carpet, a carpet of very dry moss, which the squirrel tears from the trunks of trees, and which it piles up so as to have a soft and warm couch. An entrance situated at the lower part gives access to the aerial castle; it is usually directed toward the east. On the opposite side there is another orifice by which the animal can escape if an enemy should invade the principal entrance. In ordinary times also it serves to ventilate the chamber by setting up a slight current of air. The squirrel greatly fears storms and rain, and during bad weather hastens to take refuge in his dwelling. If the wind blows in the direction of the openings, the little beast at once closes them with two stoppers of moss, and keeps well shut in as long as the storm rages.

The great Anthropoid apes have found nothing better for shelter than the squirrels' method. It must, however, be taken into account that they have much more difficulty in arranging and maintaining much heavier rooms, and in building up a shelter with larger surface.

The orang-outang, which lives in the virgin forests of the Sunda Archipelago, does not feel the need of constructing a roof against the rain. He is content with a floor established in the midst of a tree, and made of broken and interlaced branches. He piles up on this support a considerable mass of leaves and moss; for the orang does not sleep seated like the other great apes, but lies down in the manner of man, as has often been observed when he is in captivity. When he feels the cold he is ingenious enough to cover himself with the leaves of his couch.

In Upper and Lower Guinea the chimpanzee (Troglodytes niger) also establishes his dwelling on trees. He first makes choice of a large horizontal branch, which constitutes a sufficient floor for the agile animal. Above this branch he bends the neighboring boughs, crosses them, and interlaces them so as to obtain a sort of framework. When this preliminary labor is accomplished, he collects dead wood or breaks up branches and adds them to the first. Before commencing he had taken care when choosing the site that the whole was so arranged that a fork was within reach to sustain the roof. He thus constructs a very sufficient shelter.

The Troglodytes calvus, a relative of the preceding, inhabiting the same regions, as described by Du Chaillu, shows still more skill in raising his roof. A tree is always chosen for support. He breaks off boughs and fastens them by one end to the trunk, by the other to a large branch. To fix all these pieces he employs very strong creepers, which grow in abundance in his forests. Above this framework, which indicates remarkable ingenuity, the animal piles up large leaves, forming in layers well pressed down and quite impenetrable to the rain. The whole has the appearance of an open parasol. The ape sits on a branch beneath his handiwork, supporting himself against the trunk with one arm. He has thus an excellent shelter against the midday sun as well as against tropical showers.

There exists in Australia a bird with very curious customs. This is the satin bower-bird. The art displayed in this bird's constructions is not less interesting than the sociability he gives evidence of, and his desire to have for his hours of leisure a shelter adorned to his taste. The bowers which he constructs, and which present on a small scale the appearance of the arbors in our old gardens, are places for reunion and for warbling and courtship, in which the birds stay during the day, when no anxiety leads them to disperse. They are not, properly speaking, nests built for the purpose of rearing young; for at the epoch of love each couple separates and constructs a special retreat in the neighborhood of the bower. These shelters are always situated in the most retired parts of the forest, and are placed on the earth at the foot of trees. Several couples work together to raise the edifice, the males performing the chief part of the work. At first they establish a slightly convex floor, made with interlaced sticks, intended to keep the place sheltered from the moisture of the soil. The arbor rises in the centre of this first platform. Boughs vertically arranged are interlaced at the base with those of the floor. The birds arrange them in two rows facing each other; they then curve together the upper extremities of these sticks, and fix them so as to obtain a vault. All the prominences in the materials employed are turned toward the outside, so that the interior of the room may be smooth and the birds may not catch their plumage in it. This done, the little architects, to embellish their retreat, transport to it a number of conspicuous objects, such as very white stones from a neighboring stream, shells, the bright feathers of the paroquet, whatever comes to their beak. All these treasures are arranged on the earth, before the two entries to the bower, so as to form on each side a carpet, which is not smooth, but the varied colors of which rejoice the eye. The prettiest treasures are fixed into the wall of the hut. These objects are intended solely for the delight of these feathered artists. They are very careful also only to collect pieces which have been whitened and dried by the sun.

Certain humming-birds also, according to Gould, decorate their dwellings with great taste. "They instinctively fasten thereon," he stated, "beautiful pieces of flat lichen, the larger pieces in the middle, and the smaller on the part attached to the branch. Now and then a pretty feather is intertwined or fastened to the outer sides, the stem being always so placed that the feather stands out beyond the surface.

In spite of their lack of skill and the inadequacy of their organs, fish are not the most awkward architects. The species which construct nests for laying in are fairly numerous; the classical case of the stickleback is always quoted, but this is not the only animal of its class to possess the secret of the manufacture of a shelter for its eggs.

A fish of Java, the gourami (Osphronemus olfax), establishes an ovoid nest with the leaves of aquatic plants woven together. It makes its work about the size of a fist, takes no rest until it is completed, and is able to finish it in five or six days. It is the male alone who weaves this dwelling; when it is ready a female comes to lay there, and generally fills it; it may contain from six hundred to a thousand eggs.

Without doubt the class of birds furnishes the most expert artisans in the industry of the woven dwelling. In our own country we may see them seeking every day to right and left, carrying a morsel of straw, a pinch of moss, a hair from a horse's tail, or a tuft of wool caught in a bush. They intermingle these materials, making the framework of the construction with the coarser pieces, keeping those that are warmer and more delicate for the interior. These nests, attached to a fork in a branch or in a shrub, hidden in the depth of a thicket, are little masterpieces of skill and patience. To describe every form and every method would fill a volume. But I can not pass in silence those which reveal a science sure of itself, and which are not very inferior to what man can do in this line. The Lithuanian titmouse (Ægithalus pendulinus), whose works have been well described by Baldamus, lives in the marshes in the midst of reeds and willows in Poland, Galicia, and Hungary. Its nest, which resembles none met with in England, is always suspended above the water, two or three metres above the surface, fixed to a willow branch. All individuals do not exhibit the same skill in fabricating their dwelling; some are more careful and clever than others who are less experienced. Some also are obliged by circumstances to hasten their work. It frequently happens that magpies spoil or even altogether destroy with blows of their beaks one of these pretty nests. The unfortunate couple are obliged to recommence their task, and if this accident happens two or three times to the same household, it can easily be imagined that, discouraged and depressed by the advancing season, they hasten to build a shelter anyhow, only doing what is indispensable, and neglecting perfection. However this may be, the nests which are properly finished have the form of a purse, twenty centimetres high and twelve broad. At the side an opening, prolonged by a passage which is generally horizontal, gives access to the interior. Sometimes another opening is found without any passage. Every nest in the course of construction possesses this second entry, but it is usually filled up when the work is completed.

When the bird has resolved to establish its retreat, it first chooses a hanging branch presenting bifurcations which can be utilized as a rigid frame on which to weave the lateral walls of the habitation. It intercrosses wool and goats' hair so as to form two courses which are afterward united to each other below, and constitute the first sketch of the nest, at this moment like a flat-bottomed basket. This is only the beginning. The whole wall is reinforced by the addition of new material. The architect piles up down from the poplar and the willow, and binds it all together with filaments torn from the bark of trees, so as to make a whole which is very resistant. Then a couch is formed by heaping up wool and down at the bottom of the nest.

The American Baltimore oriole, also called the Baltimore bird, is a distinguished weaver. With strong stalks and hemp or flax, fastened round two forked twigs corresponding to the proposed width of nest, it makes a very delicate sort of mat, weaving into it quantities of loose tow. The form of the nest might be compared to that of a ham; it is attached by the narrow portion to a small branch, the large part being below. An opening exists at the lower end of the dwelling, and the interior is carefully lined with soft substances, well interwoven with the outward netting, and it is finished with an external layer of horse-hair, while the whole is protected from sun and rain by a natural canopy of leaves.

The rufous-necked weaver bird, as described by Brehm, shows itself equally clever. Its nest is woven with extreme delicacy, and resembles a long-necked decanter hung up with the opening below. From the bottom of the decanter a strong band attaches the whole to the branch of a tree. The yellow weaver bird of Java, as described by Forbes, constructs very similar retort-shaped nests.

These birds have no monopoly of these careful dwellings; a considerable number of genera have carried this industry to the same degree of perfection.

When animals apply themselves in association to any work, they nearly always exhibit in it a marked superiority over neighboring species among whom the individuals work in isolation. The construction of dwellings is no exception, and the nests of the sociable weaver birds of South Africa are the best constructed that can be found. These birds live together in considerable colonies; the members of an association are at least two hundred in number, and sometimes rise to five hundred. The city which they construct is a marvel of industry. They first make with grass a sloping roof, giving it the form of a mushroom or an open umbrella, and they place it in such a way that it is supported by the trunk of a tree and one or two of the branches. This thatch is prepared with so much care that it is absolutely impenetrable to water. Beneath this protecting shelter each couple constructs its private dwelling. All the individual nests have their openings below, and they are so closely pressed against one another that, on looking at the construction from beneath, the divisions can not be seen. One only perceives a surface riddled with holes like a skimmer; each of these holes is the door of a nest. The work may endure for several years; as long as there is room beneath the roof the young form pairs near their cradle; but at last, as the colony continues to increase, a portion emigrate to found a new town on another tree in the forest.

The industry of the woven dwelling does not flourish among mammals; but there is one which excels in it. This is the dwarf mouse (Mus minutus), certainly one of the smallest rodents. It generally lives amid reeds and rushes, and it is perhaps this circumstance which has impelled it to construct an aerial dwelling for its young, not being able to deposit them on the damp and often flooded soil. This retreat is not used in every season; its sole object is for bringing forth the young. It is therefore a genuine nest, not only by the manner in which it is made, but by the object it is intended to serve. The nest is made with as much delicacy as that of any bird, and no other mammal except man is capable of executing such weaver's work.

There are birds which have succeeded in solving a remarkable difficulty. Sewing seems so ingenious an art that it must be reserved for the human species alone. Yet the tailor-bird, the Orthotomus longicauda, and other species possess the elements of it. They place their nests in a large leaf which they prepare to this end. With their beaks they pierce two rows of holes along the two edges of the leaf; they then pass a stout thread from one side to the other alternately. With this leaf, at first flat, they form a horn in which they weave their nest with cotton or hair. These labors of weaving and sewing are preceded by the spinning of the thread. The bird makes it itself by twisting in its beak spiders' webs, bits of cotton, and little ends of wool. Sykes found that the threads used for sewing were knotted at the ends. It is impossible not to admire animals who have skilfully triumphed over all the obstacles met with in the course of these complicated operations.

Certain spiders, while they do not actually sew in the sense that they perforate the leaves they use to build their nest, and draw the thread through them, yet subject the leaves to an operation which can not well be called anything else but sewing it.

Certain wasps, by the material of their dwellings, approach the Japanese; they build with paper. This paper or cardboard is very strong and supplies a solid support; moreover, being a bad conductor of heat, it contributes to maintain an equable temperature within the nest. The constructions of these insects, though they do not exhibit the geometric arrangement of those of bees, are not less interesting. The paper which they employ is manufactured on the spot, as the walls of the cells develop. Detritus of every kind enters into its preparation: small fragments of wood, sawdust, etc.; anything is good. These Hymenoptera possess no organ specially adapted to aid them; it is with their saliva that they glue this dust together and make of it a substance very suitable for its purpose. The dwellings often reach considerable size, yet they are always begun by a single female, who does all the work without help until the moment when the first eggs come out; she is thus furnished with workers capable of taking a share in her task. The Vespa sylvestris builds a paper nest of this kind, hanging to the branch of a tree, like a great gray sphere prolonged to a blunt neck. The hornet's nest is similar in construction.

Gelatine nests are made by certain swallows who nest in grottoes or cliffs on the edge of the sea. After having collected from the water a gelatinous substance formed either of the spawn of fish or the eggs of mollusca, they carry this substance on to a perpendicular wall, and apply it to form an arc of a circle. This first deposit being dry, they increase it by sticking on to its edge a new deposit. Gradually the dwelling takes on the appearance of a cup and receives the workers' eggs. These dwellings are the famous swallows' nests, so appreciated by the epicures of the extreme East, which are edible in the same way as, for example, caviare.

Certain animals, whose dwelling participates in the nature of a hollow cavern, make additions to it which claim a place among the constructions with which we are now occupied.

The Anthophora parietina is in this group; it is a small bee which lives in liberty in our climate. As its name indicates, it prefers to frequent the walls of old buildings and finds a refuge in the interstices, hollowing out the mortar half disintegrated by time. The entrance to the dwelling is protected by a tube curved toward the bottom, and making an external prominence. The owner comes and goes by this passage, and as it is curved toward the earth the interior is protected against a flow of rain, while at the same time the entry is rendered more difficult for Melectes and Anthrax. These insects, in fact, watch the departure of the Anthophora to endeavor to penetrate into their nests and lay their eggs there. The gallery of entry and exit has been built with grains of sand, the débris produced by the insect in working. These grains of sand glued together form, on drying, a very resistant wall.

The other animals of which I have to speak are genuine masons, who prepare their mortar by tempering moistened earth. Every one has seen the swallow in spring working at its nest in the corner of a window. It usually establishes its dwelling in an angle, so that the three existing walls can be utilized, and to have an inclosed space there is need only to add the face. It usually gives to this the form of a quarter of a sphere, and begins it by applying earth more or less mixed with chopped hay against the walls which are to support the edifice. At the summit of the construction a hole is left for entry and exit. During the whole of its sojourn in our country the swallow uses this dwelling, and even returns to it for many years in succession, as long as its work will support the attacks of time. The faithful return of these birds to their old nest has been many times proved by attaching ribbons to their claws; they have always returned with the distinctive mark.

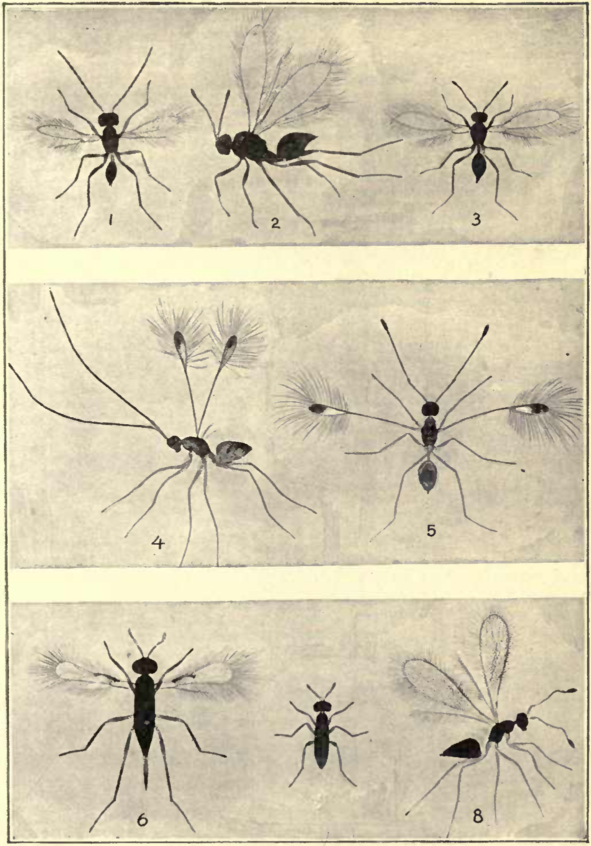
Besides the swallows, birds offer us several types of skilful construction with tempered earth.

The flamingo, which lives in marshes, can not place its eggs on the earth nor in the trunks of trees, which are often absent from its domain. It builds a cone of mud, which dries and becomes very resistant, and it prepares at the summit an excavation open to the air; this is the nest. The female broods by sitting with her legs hanging over the sides of the hillock on which her little family prospers above the waters and the damp soil.

A perch in the Danube makes a dwelling of dried earth in the form of an elliptic cupola, and prepares a semicircular opening for entry and exit.

The bird which shows itself the most skilful mason is probably the oven-bird (Furnarius rufus) of Brazil and La Plata. Its name is owing to the form of the nest which it constructs for brooding, and which has the appearance of an oven. It is very skilful and knows how to build a dome of clay without scaffolding, which is not altogether easy. Having chosen for the site of its labors a large horizontal branch, it brings to it a number of little clay balls more or less combined with vegetable débris, works them all together, and makes a very uniform floor, which is to serve as a platform for the rest of the work. When this is done, and while the foundation is drying, the bird arranges on it a circular border of mortar slightly inclined outward. This becomes hard; it raises it by a new application, this time inclined inward. All the other layers which will be placed above this will also be inclined toward the interior of the chamber. As the structure rises, the circle which terminates it above becomes more and more narrow. Soon it is quite small, and the animal, closing it with a little ball of clay, finds itself in possession of a well-made dome. Naturally it prepares an entrance; the form of this is semicircular. But this is not all. In the interior it arranges two partitions: one vertical, the other horizontal, separating off a small chamber. The vertical partition begins at one of the edges of the door, so that the air from without can not penetrate directly into the dwelling, which is thus protected against extreme variations of temperature. It is in the compartment thus formed that the female lays her eggs and broods, after having taken care to carpet it with a thick layer of small herbs.

The musk-rats of Canada live in colonies on the banks of streams or deep lakes, and construct dwellings which are very well arranged. In their methods we find combined the woven shelter with the house of built earth. Their cabins are established over the highest level of the water and look like little domes. In building them the animals begin by placing reeds in the earth; these they interlace and weave so as to form a sort of vertical mat. They plaster it externally with a layer of mud, which is mixed by means of the paws and smoothed by the tail. At the upper part of the hut the reeds are not pressed together or covered with earth, so that the air may be renewed in the interior. A dwelling of this kind, intended to house six or eight individuals who have combined to build it, may measure up to sixty-five centimetres in diameter. There is no door directly opening on to the ground. A subterranean gallery starts from the floor and opens out beneath the water. It presents secondary branches, some horizontal, through which the animal goes in search of roots for food, while others descend vertically to pits specially reserved for the disposal of ordure.



Fairy Flies (magnified 30 diameters)

1, Caraphractus Cinctus, Male; 2, 3, same, Female; 4, 5, Mymar Pulchellus, Male and Female; 6, 7, Prestwichia Aquatica, Female and Male: 8, Cosmocomo Fumipennis, Female

But it is, above all, the beaver (Castor fibre) who exhibits the highest qualities as an engineer and mason. This industrious and sagacious rodent is well adapted to inconvenience the partisans of instinct as an entity, apart from intelligence, which renders animals similar to machines and impels them to effect associated acts, without themselves being able to understand them, and with a fatality and determination from which they can under no circumstance escape.

The civilization of the beaver has perished in the presence of man's civilization, or rather of his persecution. In regions where it is tracked and disturbed by man the beaver lives in couples, and is content to hollow out a burrow like the otter's, instead of showing its consummate art. It merely vegetates, fleeing from enemies who are too strong for it, and depriving itself of a dangerous comfort. But when the security of solitude permits these animals to unite in societies, and to possess, without too much fear, a pond or a stream, they then exhibit all their industry.

They build very well arranged dwellings, although at first sight they look like mere piles of twigs, branches, and logs heaped in disorder on a small dome of mud. At the edge of a pond each raises his own lodge, and there is no work by the colony in common. If, however, there is a question of inhabiting the bank of a shallow stream, certain preliminary works become necessary. The rodents establish a dam, so that they may possess a large sheet of water which may be of fair depth, and above all constant, not at the mercy of the rise and fall of the stream. A sudden and excessive flood is the one danger likely to prove fatal to these dikes; but even our own constructions are threatened under such circumstances.

When the beavers, tempted by abundance of willows and poplars, of which they eat the bark and utilize the wood in construction, have chosen a site, and have decided to establish a village on the edge of the water, there are several labors to be successively accomplished. Their first desire is to be in possession of a large number of felled trunks of trees. To obtain them they scatter themselves in the forest bordering the stream and attack saplings of from twenty to thirty centimetres in diameter. They are equipped for this purpose. With their powerful incisors, worked by strong jaws, they can soon gnaw through a tree of this size. But they are capable of attacking trees even more than 100 cm. in diameter and some forty metres in height with great skill and adaptability; "no better work could be accomplished by a most highly finished steel cutting tool, wielded by a muscular human arm" (Martin). They operate seated on their hindquarters, and they make their incision in the wood with a feather edge. It was once supposed that they always take care so to direct their wood-cutting task that the tree may fall on the water-side, but this is by no means the case, and appears to be simply due, as Martin points out, to the fact that trees by the water-side usually slope toward the water. The austerity of labor alternates, it may be added, with the pleasures of the table. From time to time the beavers remove the bark of the fallen trees and feed on it.

Mr. Lewis H. Morgan studied the American beaver with great care and thoroughness, more especially on the southwest shore of Lake Superior; he devotes fifty pages to the dams, and it is worth while to quote his preliminary remarks regarding them: "The dam is the principal structure of the beaver. It is also the most important of his erections, as it is the most extensive, and because its production and preservation could only be accomplished by patient and long-continued labor. In point of time, also, it precedes the lodge, since the floor of the latter and the entrances to its chamber are constructed with reference to the level of the water in the pond. The object of the dam is the formation of an artificial pond, the principal use of which is the refuge it affords to them when assailed, and the water-connection it gives to their lodges and to their burrows in the banks. Hence, as the level of the pond must, in all cases, rise from one to two feet above these entrances for the protection of the animal from pursuit and capture, the surface-level of the pond must, to a greater or less extent, be subject to their immediate control. As the dam is not an absolute necessity to the beaver for the maintenance of his life, his normal habitation being rather natural ponds and rivers, and burrows in their banks, it is in itself considered a remarkable fact that he should have voluntarily transferred himself, by means of dams and ponds of his own construction, from a natural to an artificial mode of life.

"Some of these dams are so extensive as to forbid the supposition that they were the exclusive work of a single pair or of a single family of beavers; but it does not follow, as has very generally been supposed, that several families, or a colony, unite for the joint construction of a dam. After careful examination of some hundreds of these structures, and of the lodges and burrows attached to many of them, I am altogether satisfied that the larger dams were not the joint product of the labor of large numbers of beavers working together, and brought thus to immediate completion; but, on the contrary, that they arose from small beginnings, and were built upon year after year, until they finally reached that size which exhausted the capabilities of the location; after which they were maintained for centuries, at the ascertained standard, by constant repairs. So far as my observations have enabled me to form an opinion, I think they were usually, if not invariably, commenced by a single pair, or a single family of beavers; and that when, in the course of time, by the gradual increase of the dam, the pond had become sufficiently enlarged to accommodate more families than one, other families took up their residence upon it, and afterward contributed by their labor to its maintenance. There is no satisfactory evidence that the American beavers either live or work in colonies; and if some such cases have been observed, it will either be found to be an exception to the general rule, or in consequence of the sudden destruction of a work upon the maintenance of which a number of families were at the time depending.

"The great age of the larger dams is shown by their size, by the large amount of solid materials they contain, and by the destruction of the primitive forest within the area of the ponds; and also by the extent of the beaver-meadows along the margins of the streams where dams are maintained, and by the hummocks formed upon them by and through the annual growth and decay of vegetation in separate hills. These meadows were undoubtedly covered with trees adapted to a wet soil when the dams were constructed. It must have required long periods of time to destroy every vestige of the ancient forest by the increased saturation of the earth, accompanied with occasional overflows from the streams. The evidence from these and other sources tends to show that these dams have existed in the same places for hundreds and thousands of years, and that they have been maintained by a system of continuous repairs.

"At the place selected for the construction of a dam, the ground is usually firm and often stony, and when across the channel of a flowing stream, a hard rather than a soft bottom is preferred. Such places are necessarily unfavorable for the insertion of stakes in the ground, if such were, in fact, their practice in building dams. The theory upon which beaver-dams are constructed is perfectly simple, and involves no such necessity. Soft earth, intermixed with vegetable fibre, is used to form an embankment, with sticks, brush, and poles imbedded within these materials to bind them together, and to impart to them the requisite solidity to resist the effects both of pressure and of saturation. Small sticks and brush are used, in the first instance, with mud and earth and stones for down-weight. Consequently these dams are extremely rude at their commencement, and they do not attain their remarkably artistic appearance until after they have been raised to a considerable height, and have been maintained, by a system of annual repairs, for a number of years."*

There are two different kinds of beaver-dams, although they are both constructed on the same principle. One, the stick-dam, consists of interlaced stick and pole work below, with an embankment of earth raised with the same material upon the upper or water face. This is usually found in brooks or large streams with ill-defined banks. The other, the solid-bank dam, is not so common nor so interesting, and is usually found on those parts of the same stream where the banks are well defined, the channel deep, and the current uniform. In this kind the earth and mud entirely buries the sticks and poles, giving the whole a solid appearance. In the first kind the surplus water percolates through the dam along its entire length, while in the second it is discharged through a single opening in the crest formed for that purpose.

The materials being prepared in the manner I have previously described, the animals make ready to establish their dike. They intermix their materials —driftwood, green willows, birch, poplars, etc.—in the bed of the river, with mud and stones, so making a solid bank, capable of resisting a great force of

* L. H. Morgan, *The American Beaver and his Works,* Philadelphia, 1868, pp. 82-86.

water; sometimes the trees will shoot up forming a hedge. The dam has a thickness of from three to four metres at the base, and about sixty centimetres at the upper part. The wall facing up-stream is sloping, that directed down-stream is vertical; this is the best arrangement for supporting the pressure of the mass of water which is thus expended on an inclined surface. In certain cases beavers carry hydraulic science still further. If the course of the water is not very rapid, they generally make an almost straight dike, perpendicular to the two banks, as this is then sufficient; but if the current is strong, they curve it so that the convexity is turned up-stream. In this way it is much better fitted to resist. Thus they do not always act in the same way, but arrange their actions so as to adapt them to the conditions of the environment.

The embankment being completed, the animals construct their lodges. Fragments of wood, deprived of the bark, are arranged and united by clay or mud which the beavers take from the river-side, transport, mix, and work with their forepaws. During a single night they can collect as much mud at their houses as amounts to some thousands of their small handfuls. They thus plaster their houses with mud every autumn; in the winter this freezes as hard as a stone and protects them from enemies. These cabins form domes from three to four metres in diameter at the base, and from two to two and a half metres in height. The floor is on a level with the surface of the artificial pond. A passage sinks in the earth and opens about one and a half metres below the level of the water, so that it can not be closed up by ice during the severe winters of these regions.

Within, near the entry, the beavers form, with the aid of a partition, a special compartment to serve as a storehouse, and they there pile up enormous heaps of nenuphar roots as provisions for the days when ice and snow will prevent them from barking the young trunks.

A dwelling of this kind may last for three or four years, and the animal here tranquilly enjoys the fruits of its industry as long as man fails to discover the retreat; for the beaver can escape by swimming from all carnivorous animals excepting, perhaps, the otter. During the floods the level of the water nearly reaches the hut; if the inundation is prolonged and the animal runs the risk of being asphyxiated beneath his dome, it breaks through the upper part with its teeth and escapes. When the water returns to its bed the beaver comes back, makes the necessary repairs, and resumes the usual peaceful course of its life.

We have thus seen, from a shapeless hole to these complex dwellings, every possible stage; we have found among animals the rudiments of the different human habitations, certain animals, indeed, having arrived at a degree of civilization which man himself in some countries has not yet surpassed, or even indeed yet attained.

MAN'S FIRST APPEARANCE
—Boyd Dawkins

THE characteristics of the evolution of living forms may be summed up as follows:

I. Eocene—in which the placental mammals now on earth were represented by allied forms belonging to existing orders and families. Living orders and families appear; lemurs (Lemuridæ) in Europe and North America. Evidence found in fresh-water and marine strata; lignites.

II. Miocene—in which the alliance between living and placental mammals is more close than before. Living genera appear; apes (Simiadæ) in Europe and North America. Evidence—fresh-water and marine strata; volcanic débris (Auvergne); lignites.

III. Pliocene—in which living species of placental mammals appear. Living species appear; apes (Simiadæ) in Southern Europe. Evidence found in fresh-water and marine strata; volcanic débris (Auvergne).

IV. Pleistocene—in which living species of placental mammals are more abundant than the extinct. Man appears; Anthropidæ; the palæolithic hunter; living species abundant. Evidence—refuse-heaps, contents of caves, river deposits, submarine forests, bowlder clay, moraines, marine sands, and shingle.

V. Prehistoric—in which domestic animals and cultured fruits appear. Man abundant, domestic animals, cultivated fruits, spinning, weaving, pottery-making, mining, commerce; the neolithic, bronze, and iron stages of culture. Evidence—camps, habitations, tombs, refuse-heaps, surface accumulation, caves, alluvia, peat bogs, submarine forests, raised beaches.

VI. Historic—in which the events are recorded in history. Evidence—documents, refuse-heaps, caves, tombs.

The orders, families, genera, and species in the above summary, when traced forward in time, fall into the shape of a genealogical tree, with its trunk hidden in the secondary period, and its branchlets (the living species) passing upward from the Pliocene, a tree of life with living Mammalia for its fruits and foliage. Were the extinct species taken into account, it would be seen that they fill up the intervals separating one living form from another, and that they too grow more and more like the living forms as they approach nearer to the present day. It must be remembered that in the above definitions the fossil marsupials are purposely ignored, because they began their specialization in the secondary period, and had arrived in the Eocene at the stage which is marked by the presence of living genus—the opossum (Didelphys).

It will be seen that our inquiry into the antiquity of man is limited to the last four of the divisions. The most specialized of all animals can not be looked for until the higher Mammalia by which he is surrounded were alive. We can not imagine him in the Eocene age, at a time when animal life was not sufficiently differentiated to present us with any living genera of placental mammals. Nor is there any probability of his having appeared on the earth in the Miocene, because of the absence of higher placental mammals belonging to living species. It is most unlikely that man should have belonged to a fauna in which no other living species of mammal was present. He belongs to a more advanced stage of evolution than the mid-Miocene of Thenay. Up to this time the evolution of the animal kingdom had advanced no further than the Simiadæ in the direction of man; and the apes then haunting the forests of Italy, France, and Germany represent the highest type of those on earth.

We may also look at the question from another point of view. If man were upon the earth in the Miocene age, it is incredible that he should not have become something else in the long lapse of ages, and during the changes in the condition of life, by which all the Miocene land Mammalia have been so profoundly affected that they have been either exterminated or have assumed new forms. Nor in the succeeding Pliocene age can we expect to find man upon the earth, because of the very few living species of placental mammals then alive. It is not until we arrive at the succeeding stage, or the Pleistocene, when living species of Mammalia began to abound, that we meet with indisputable traces of the presence of man on the earth. The rudely chipped implements of the River-drift hunter lie scattered through the late Pleistocene river deposits in southern and eastern England in enormous abundance, and as a rule in association with the remains of animals of Arctic and of warm habit, as well as some one or other of the extinct species of reindeer and hippopotamus along with mammoth and woolly rhinoceros.

The geographical change in Northern Europe at the close of the forest-bed age was very great. The forest of the North Sea sank beneath the waves, and Britain was depressed to a depth of no less than 2,300 feet in the Welsh Mountains, and was reduced to an archipelago of islands, composed of what are now the higher lands. The area of the English Channel was also depressed, and the "silver streak" was wider than it is now, as is proved by the raised beach at Brighton, at Brackelsham, and elsewhere, which marks the sea-line of the largest island of the archipelago, the Southern Island, as it may be termed, the northern shores of which extended along a line passing from Bristol to London. The northern shore of the Continent at this time extended eastward from Abbeville, north of the Erzgebirge, through Saxony and Poland, into the middle of Russia, Scandinavia being an island from which the glaciers descended into the sea. This geographical change was accompanied by a corresponding change in climate. Glaciers descended from the higher mountains to the sea level, and icebergs, melting as they passed southward, deposited their burdens of clay and sand which occupy such a wide area in the portions then submerged of Britain and the Continent. This depression was followed by a re-elevation, by which the British Isles, a part of the Continent, all the large tract of country within the 100-fathom line, again became the feeding-grounds of the late Pleistocene mammalia.

An appeal to the animals associated with the River-drift implements will not help us to fix the exact relation of man to these changes, because they were in Britain before as well as after the submergence, and were living throughout in those parts of Europe which were not submerged. It can only be done in areas where the submergence is clearly defined. At Salisbury, for instance, the River-drift hunter may have lived either before, during, or after the southern counties became an island. When, however, he hunted the woolly and leptorhine rhinoceros, the mammoth, and the horse, in the neighborhood of Brighton, he looked down upon a broad expanse of sea, in the spring flecked with small icebergs such as those which dropped their burdens in Brackelsham Bay. At Abbeville, too, he hunted the mammoth, reindeer, and horse down to the mouth of the Somme on the shore of the glacial sea. The evidence is equally clear that the River-drift hunter followed the chase in Britain after it had emerged from beneath the waters of the glacial sea, from the fact that the river deposits in which his implements occur either rest upon the glacial clays, or are composed of fragments derived from them, as in the oft-quoted case of Hoxne and Bedford. Further, it is very probable that he may have wandered close up to the edge of the glaciers then covering the higher hills of Wales and the Pennine chain. The severity of the climate in winter at this time in Britain is proved, not merely by the presence of the Arctic animals, but by the numerous ice-borne blocks in the river gravels dropped in the spring after the break-up of the frosts.

The River-drift man is proved, by the implements which he left behind, to have wandered over the whole of France, and to have hunted the same animals in the valley of the Loire and the Garrone, as in the valley of the Thames. In the Iberian peninsula he was also a contemporary of the African elephant, the mammoth, and the straight-tusked elephant, and he occupied the neighborhood both of Madrid and Lisbon. He also ranged over Italy, leaving traces of his presence in the Abruzzo, and in Greece he was a contemporary of the extinct pygmy hippopotamus (H. Pentlandi). South of the Mediterranean his implements have been met with in Oran, and near Kolea in Algeria, and in Egypt in several localities. At Luxor they have been discovered by General Pitt-Rivers in the breccia, out of which are hewn the tombs of the kings. In Palestine, they have been obtained by the Abbé Richard between Mount Tabor and the Sea of Tiberias; and by Mr. Stopes between Jerusalem and Bethlehem. Throughout this wide area the implements, for the most part of flint or of quartzite, are of the same rude types, and there is no difference to be noted between the hatchets found in the caves of Cresswell in Derbyshire and those of Thebes, or between those of the valley of the Somme and those of Palestine. The River-drift hunter ranged over the Indian peninsula from Madras as far north as the valley of the Nerbudda. Here we find him forming part of a fauna in which are species now living in India, such as the Indian rhinoceros and the arnee, and extinct types of oxen and elephants. There are two extinct hippopotami in the rivers, and living gavials, turtles, and tortoises. It is plain, therefore, that at this time the fauna of India stood in the same relation to the present fauna as the European fauna of the late Pleistocene does to that now living in Europe. In both there was a familiar association of extinct and living forms, from both the genus hippopotamus has disappeared in the lapse of time, and in both man forms the central figure.

We are led from the region of tropical India to the banks of the Delaware, in New Jersey, by the recent discoveries of Dr. C. C. Abbott. Here, too, living and extinct species are found side by side.

Thus in our survey of the group of animals surrounding man when he first appeared in Europe, India, and North America, we see that in all three regions, so widely removed from each other, the animal life was in the same stage of evolution, and "the old order" was yielding "place unto the new." The River-drift man is proved by his surroundings to belong to the Pleistocene age in all three. The evidence of Palæolithic man in South Africa seems to me unsatisfactory, because the age of the deposits in which the implements are found has not been decided.

The identity of the implements of the River-drift hunter proves that he was in the same rude state of civilization, if it can be called civilization, in the Old and New Worlds, when the hands of the geological clock pointed to the same hour. It is not a little strange that his mode of life should have been the same in the forests to the north and south of the Mediterranean, in Palestine, in the tropical forests of

India, and on the western shore of the Atlantic. The hunter of the reindeer in the valley of the Delaware was to all intents and purposes the same sort of savage as the hunter of the reindeer on the banks of the Wiley or of the Solent.

It does not, however, follow that this identity of implements implies that the same race of men were spread over this vast tract. It points rather to a primeval condition of savagery from which mankind has emerged in the long ages which separate it from our own time. It may further be inferred, from his widespread range, that the River-drift man (assuming that mankind sprang from one centre) must have inhabited the earth for a long time, and that his dispersal took place before the glacial submergence and the lowering of the temperature in Northern Europe, Asia, and America. It is not reasonable to suppose that the Straits of Behring would have offered a free passage, either to the River-drift man from Asia to America, or to American animals from America to Europe, or *vice versâ,* while there was a vast barrier of ice or of sea, or of both, in the high northern latitudes. I therefore feel inclined to view the River-drift man as having invaded Europe in pre-glacial time along with the other living species which then appeared. The evidence, as I have already pointed out, is conclusive that he was also glacial and post-glacial.

In all probability, the birthplace of man was in a warm, if not a tropical, region of Asia—"in a garden of Eden"; and from this the River-drift man found his way into those regions where his implements occur. In India, he was a member of a tropical fauna, and his distribution in Europe and along the shores of the Mediterranean proves him to have belonged either to the temperate or the southern fauna in those regions. It will naturally be asked, To what race can the River-drift man be referred? The question, in my opinion, can not be answered in the present stage of the inquiry, because the few fragments of human bones discovered along with the implements are too imperfect to afford any clew. Nor can we measure the interval in terms of years which separates the River-drift man from the present day, either by assuming that the glacial period was due to astronomical causes, and then proceeding to calculate the time necessary for them to produce their result, or by an appeal to the erosion of valleys, or the retrocession of waterfalls. The interval must, however, have been very great to allow of the changes in geography and climate, and the distribution of animals which has taken place—the succession of races, and the development of civilization before history began. Standing before the rock-hewn tombs of the kings at Luxor, we may realize the impossibility of fixing the time when the River-drift hunter lived in the side of the ancient Thebes, or of measuring the lapse of time between his days and the splendor of the civilization of Egypt. In this inquiry I have purposely omitted all reference to the successor of the River-drift man in Europe—the Cave man—who was in a higher stage of the hunter civilization. In the course of my remarks you will have seen that the story told by the rudely chipped implements found at our very door forms a part of the wider story of the first appearance of man and of his distribution on the earth.

MAN'S PRIMITIVE CONDITION.—Duke of Argyll

As the question of man's origin is different from the question of his antiquity, and as the antiquity of man is a different question from his primitive condition, so again the last question includes within itself several different matters of inquiry. There is first the question, What consciousness had primeval man of moral obligation, and what communion with his Creator? Next there is the question, What were his innate intellect or understanding? And, thirdly, there is the question, What was his condition in respect to knowledge, whether as the result of intuition or as the result of teaching? Sir J. Lubbock speaks of primeval man as having been in a condition of "utter barbarism." But no one, speaking philosophically, has a right to use such terms as "barbarism" and "civilization" without some definition of their meaning. What were those faculties which made the first creature who possessed them "worthy to be called a man"? A mind capable of reason, disposed to reason, and able to acquire, to accumulate, and to transmit knowledge—this is the distinctive attribute of man. The first being "worthy to be so called" must have had such a mind. But it could not properly be said of such a being, on the ground merely of his ignorance of mechanical arts, that he was in a condition of "utter barbarism," if he were at the same time conscious of moral obligations and obedient to them.

Wherever a brutal or savage custom prevails it is at once assumed to be a sample of the original condition of mankind. And this in the teeth of facts which prove that many of such customs not only may have been, but must have been, the result of corruption. Take cannibalism as one of these. Sir J. Lubbock seems to admit that this loathsome practice was not primeval, probably because he considers it as unnatural. And so it is—that is to say, it is against the better nature of man; but the fact of its existence proves that within the limits of that nature there are elements liable to perversions even so horrible as this. And so we come upon the fact of the two natures of man, and of the power of the worst parts of his nature to overcome the best. It is thus that customs the most cruel and depraved become established. But if this be the explanation, and the only possible explanation, of cannibalism, is it not evident that this may also be the explanation of other customs which are violent and horrible only in a less degree? Cruel rites of worship and savage customs as regards marriage and the relation of the sexes come under the same category. Cannibalism is only an extreme case of a general law, and it is a crucial test of the fallacy of a whole class of arguments commonly assumed by those who support the savage theory respecting the primeval condition of mankind.

The great difficulty of teaching many savages the arts of civilized life is no proof whatever that the various degrees of advance toward the knowledge of those arts which are actually found among semi-barbarous nations may not have been of strictly indigenous growth. Thus it appears that one tribe of Red Indians, called "Mandans," practiced the art of fortifying their towns. Surrounding tribes, although they saw the advantages derived from this art, yet never practiced it, and never learned it.

I do not agree with the late Archbishop of Dublin that we are entitled to assume it as a fact that, as regards the mechanical arts, no savage race has ever raised itself. Whately says that "the earliest generations of mankind had received only very limited, and what may be called elementary, instruction, enough merely to enable them to make further advances afterward by the exercise of their natural powers." But how much was this "enough"? And what is meant by "instruction," as distinguished from inborn or intuitive powers of observation and of reasoning? May not this have been the form in which the Creator first "instructed" man? For here it is important to observe that in direct proportion as we assume man's primitive condition to have been such as to require elementary teaching, in the same proportion do we suppose that his primitive condition in respect to intellect was low and weak. Accordingly, Whately assumes as an indisputable fact, that man has no instincts such as enable the lower animals to construct nests, cells, and lairs. My own belief is that this is an assumption which is not only unproved, but one which in all probability is false. As Whately himself admits, "man is an animal" as well as the creatures that are below him. It is true that he has not instincts of the same kind as they have. But this is no proof whatever that he has not, and had not originally, instincts which stand in strict correlation with the peculiarities of his higher physical organization. There are many facts which go far to prove that man has, and must always have had, instincts which afford all that is required as a starting-ground for advance in the mechanical arts. Few persons have reflected on how much is involved in the most purely instinctive acts, such as the throwing of a stone or the wielding of a stick as a weapon of offence. Both these simple acts involve the great principle of the use of artificial tools. Even in the most rudimentary form the use of an implement fashioned for a special purpose is absolutely peculiar to man, and arises necessarily and instinctively out of the structure of his body. The bodies of the lower animals are so constructed that such implements as they are capable of directing are all supplied in the form of bodily organs. All effects which they desire to produce, or are capable of producing, are effected directly by the use of those organs under the guidance of implanted instincts. There are some very curious cases among the lower animals of a near approach to the principle involved in the use of tools—that is to say, the use of natural force through artificial means. Thus the common gray or hooded crow is constantly in the habit of lifting shell-fish to a certain height in the air and then letting them fall upon the rocks of the shore in order to break the shells. Some species of monkey will even use any stone which may be at hand for the purpose of striking and breaking a nut. The elephant tears branches from the trees and uses them as an artificial tail to fan himself and to keep off the flies. But between these rudiments of intellectual perception and the next step—that of adapting and fashioning an instrument for a particular purpose—there is a gulf in which lies the whole immeasurable distance between man and the brutes. In no case whatever do they ever use an implement made by themselves as an intermediate agency between their bodily organs and the work which they desire to do. Man, on the contrary, is so constructed that in almost everything he desires to do he must employ an agency intermediate between his bodily organs and the effect which he wishes to produce. But this necessity, which in one aspect is a physical disability, is correlated with a mind capable of invention, and with certain implanted instincts which involve all the rudiments of mechanical skill. The man who first lifted a stone and threw it, practiced an art which not one of the lower animals is capable of practicing. This is an act which in all probability is as strictly instinctive and natural to man as it is to a dog to bite, or to a bull to charge. Yet the act involves the idea and the knowledge of projectile force and of the arts by which direction can be given to that force. The wielding of a stick is, in all probability, an act equally of primitive intuition, and from this to the throwing of a stick, and the use of javelins, is an easy and natural transition. Simple as these acts are, they involve both physical and mental powers capable of all the developments which we see in the most advanced industrial arts.

And here it is important to observe that even if savage races be taken as the type of man's primeval condition, the evidence afforded by these races is all in favor of the conclusion that, as regards his characteristic mental powers, man has always been man, and nothing less. There is quite as much ingenuity and skill in the manufacture of a knife of flint as in the manufacture of a knife of iron. And the skill displayed by the men who used stone implements is not confined to that which is involved in the selection of mineral substances suitable for the purpose. That skill is also eminently displayed in the use made of those stone implements after they had been fashioned. The smaller implements of bone, or of horn, or of wood which the stone knives and hatchets were employed to make are often highly ingenious, and sometimes eminently beautiful. The truth is that high qualities of reasoning and ready faculties of observation are called forth in the inverse ratio of the acquired knowledge with which they are provided, and from which they start.

It matters not which of the two theories we adopt in regard to the origin of the human race, whether we suppose it to have proceeded from one or from two, or even from several different centres of creation; it matters not whether we suppose with Sir J. Lubbock that the "first being worthy to be called a man" was born of some inferior creature, or whether we believe with Whately, that he was truly human in his powers, but required some "elementary instruction to enable his faculties to begin their work." In any case we may safely assume that man must have begun his course in some one or more of those portions of the earth which are genial in climate, rich in natural fruits, and capable of yielding the most abundant return to the very simplest arts. It is under such conditions that the first establishment of the human race can be most easily understood; nay, it is under such conditions only that it is conceivable at all. And as these are the conditions which would favor the first establishment and the most rapid increase of man, so also are these the conditions under which knowledge would most rapidly accumulate, and the earliest possibilities of material civilization would arise.

Now what are the changes of external circumstance which first, in the natural course of things, would bring an adverse influence to bear upon mankind? Here again we are on firm ground, because we know one great cause which has been always operating, and we know its natural and inevitable effects. This cause is simply the law of increase. It is the consequence of that law that population is always pressing upon the limits of subsistence. Hence the necessity of migrations, and the force which has propelled successive generations of men further and further, in ever-widening circles round the original centre or centres of their birth. Then, as it would always be the weaker tribes who would be driven from the ground which had become overstocked, and as the lands to which they went forth were less and less hospitable in climate and productions, the struggle for life would be always harder. And so it always happens in the natural and necessary course of things, that the races which were driven furthest would be the rudest—the most engrossed in the pursuits of mere animal existence.

Is it not true that the lowest and rudest tribes in the population of the globe have been found at the furthest extremities of its great continents, and in the distant islands which would be the last refuge of the victims of violence and misfortune? "The New World" is the continent which presents the most uninterrupted stretch of habitable land from the highest northern to the lowest southern latitude. On the extreme north we have the Eskimo, or Inuit race, maintaining human life under conditions of extremest hardship, even amid the perpetual ice of the polar seas. And what a life it is! Watching at the blowhole of a seal for many hours, in a temperature of 75° below freezing-point, is the constant work of the Inuit hunter. And when at last his prey is struck, it is his luxury to feast upon the raw blood and blubber. To civilized man it is hardly possible to conceive a life so wretched, and in many respects so brutal, as the life led by this race during the long lasting night of the Arctic winter. Not even the most extravagant theorist, as regards the plurality of human origins, can suppose that there was an Eskimo Adam—that any man was originally created or developed in the icy regions round the pole. Here then we have a case, beyond all question, of races driven by wars and migrations from the more temperate regions of the globe. So long as they were still in those regions, the ancestors of the Eskimo must have lived in another manner, and must have had wholly different habits. The rigors of the region they now inhabit have reduced this people to the condition in which we now see them, and whatever arts their fathers knew, suited to more genial climates, have been, and could not fail to be, utterly forgotten.

And now let us pass to the other extremity of the great continent of America—to Cape Horn, and to the island off it, which projects its desolate rocks into one of the most inhospitable climates in the world. The inhabitants of Tierra del Fuego are perhaps the most degraded among the races of mankind. How could they be otherwise? "Their country," says Mr. Darwin, "is a broken mass of wild rocks, lofty hills, and useless forests; and these are viewed through mists and endless storms. The habitable land is reduced to the stones of the beach. In search of food they are compelled to wander unceasingly from spot to spot, and so steep is the coast that they can only move about in their wretched canoes." They are habitual cannibals, killing and eating their old women before they kill their dogs, for the sufficient reason, as explained by themselves—"Doggies catch otters, old women no." Well might Darwin add, "While beholding these savages one asks, Whence have they come? What could have tempted, or what change compelled, a tribe of men to leave the fine regions of the north, to travel down the Cordillera, or backbone of America, to invent and build canoes which are not used by the tribes of Chili, Peru, and Brazil, and then to enter on one of the most inhospitable countries within the limits of the globe?" There can be but one explanation. Quarrels and wars between tribe and tribe, induced by the mere increase of numbers and the consequent pressure on the means of subsistence, have been always, ever since man existed, driving the weaker races further and further from the older settlements of mankind. And when the ultimate points of the habitable world are reached, the conditions of existence cause and necessitate a savage and degraded life. Darwin gives the true explanation of their condition when he says, "How little can the higher powers of the mind be brought into play! What is there for imagination to picture, for reason to compare, for judgment to decide upon?" The case of the Fuegians is a case in which there can be no doubt whatever of the causes of their degraded condition. On every side of them, and in proportion as we recede from their wretched country, the surrounding tribes are less wretched and better acquainted with the simpler arts. And it is remarkable that in the case of this people we have proof of another point of great interest and importance, viz., this—that even the most degraded savages have all the perfect attributes of humanity, which can be and are developed the moment they are placed under favorable conditions. Captain Fitzroy had in 1830 carried off some of these people to England, where they were taught the habits and the arts of civilized life. Of one of these, who was taken back to his own country in the *Beagle*, Mr. Darwin tells us that his "intellect was good," and of another that he had a "nice disposition." We see, therefore, that every fact and circumstance connected with the Fuegians agrees with the supposition that their "utter barbarism" was due entirely to the cruel conditions of their life, and the wretched country into which they had been driven. The Bushmen of South Africa are another case in point. It seems to be clearly ascertained that they belong to the same race as other tribes who are far less degraded, and that they are simply the descendants of outcasts driven to the woods and rocks. So, again, among the great islands of the Pacific, the natives of Van Diemen's Land were the most utterly degraded of all the Polynesian races.

With these facts staring us in the face, connecting themselves in an obvious order with causes which we know to be all operating in one direction, is it not absurd to argue that the condition of these outcasts of the human family can be assumed as representing the aboriginal condition of man? Is it not certain that whatever advances toward civilization may have been made among their progenitors, such advances must necessarily have been lost under the conditions to which their children are reduced?

And now we can better estimate the value to be set on the arguments which have been founded on the rude implements found in the river drifts and in the caves of Northern Europe. I, for one, accept the evidence which geology affords that these implements are of very ancient date. I accept too the evidence which that science affords, that these implements were in all probability the ice hatchets and rude knives used by tribes which toward the close of the glacial age had pushed their way to the furthest limits of the lands which were then habitable. And what follows? The inevitable conclusion is, that it must be about as safe to argue from those implements as to the condition of man at that time, in the countries of his primeval home, as it would be in our own day to argue from the habits and arts of the Eskimo as to the state of civilization in London or in Paris.

RACES OF MANKIND
—WILLIAM HUGHES

IT is estimated that the earth is inhabited, at the present time, by 1,450 millions of human beings, who are distributed over its surface in the manner shown in the following table:

	Area in British square miles	Population	Population to square mile
Europe	3,700,000	320,000,000	86
Asia	17,000,000	830,000,000	47
Africa	12,000,000	200,000,000	16
North America (including West Indies)	8,600,000	68,000,000	8
South America	7,000,000	28,000,000	4
Oceania	3,000,000	4,000,000	1

Europe is, therefore, relatively to its size, by much the most populous division of the globe, though Asia contains the highest number of inhabitants—amounting, indeed, to little less than two-thirds of the entire human race. The New World is very much less populated by man than the older known portions of the globe, though its capabilities for the support of man fully equal those of any of the continents of the

Eastern Hemisphere. Australia, and the scattered islands of the Pacific Ocean, are the least populous portions of the carth, the total present number of their inhabitants amounting to a mere fraction of the entire number.*

The numerical distribution of mankind undergoes great change in the present day, when emigration from over-populated lands to distant parts of the globe is conducted on so extensive a scale. But this affects the distribution of *race* in much higher measure than it does the merely numerical distribution of man. The fast-increasing numbers of the settlers in the fertile plains and river valleys of the New World, descendants of European colonists, perhaps hardly more than replaces, numerically, the native races who occupied the same regions prior to the first visit of the white man to their shores. It is the tendency, everywhere, of the native races to decay before the white settler. Wars, famine, epidemic diseases, and various social causes, again, tend to keep down the total number of the human family—at any rate, to

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* The figures given in the above table represent no more than an approximate estimate. It is only in the case of Europe that we possess the means of making such calculations with any approach to accuracy. The amount of the population of China alone has been stated with wide variations—the estimates ranging between two hundred millions and more than double that number. We adopt above the higher number, which appears to be confirmed by the general testimony of observers. The number of inhabitants within the African continent (and especially within those portions of it populated by the negro race) is scarcely more than a guess: the figures given above are probably rather below than in excess of the truth.

check the more rapid numerical growth which it would otherwise exhibit.

The generally recognized ethnological division of mankind, with reference to race, is into three leading families—the Caucasian, Mongolian, and Negro. Two other families—the Malay and the American—are commonly added to these, making five in the total. The first-named division is that suggested by the illustrious French naturalist, Cuvier. The five-fold division is due to the German philosopher, Blumenbach. In the scheme of the former, the Malay and American are regarded as sub-varieties—the one of the Caucasian and the other of the Mongolian family. Other writers again enumerate a much greater number of varieties of mankind, each possessing characters sufficiently distinct to entitle it to be regarded as a separate family.

[In using the word *race,* as applied to different families of man, the division must be understood as implying "variety" only—not species. There is no *specific* difference in the various members of the human family—no difference, that is, which implies anything in contradiction to the assumption that all mankind have had a common origin, springing from a single pair. The human family differs in this regard from all the lower members of the animal kingdom. The order "bimana" (*i. e., two-handed*), to which, in scientific classification, man is referred, comprises only a single genus, and a single species.

The characteristic points of difference between the great families of mankind above referred to are the color of the skin, eyes, and hair (with the nature of the latter, whether curled, lank, woolly, or frizzled), and the shape of the skull. All other physical differences, as regards stature, form of limbs, and general outline of body, seem capable of ready explanation by reference to opposite conditions of climate, food, and habits of social life. But between the Caucasian and the Negro, or the latter and the Mongol, there is a broad and strongly marked difference, and one that extends over the whole historic period.]

The distinguishing attributes of the Caucasian race, physically considered, are the oval form of the skull with the generally symmetrical shape of the entire head and frame of body. The face is of oval form, the features moderately prominent, the forehead arched, the cheek-bones only slightly projecting, the mouth small, the chin full and round; with the skin generally of light color (varying, however, from white to a deep brown, or swarthy, hue), the eyes and hair of various hue, and the latter often curling. The facial angle* is greater in the case of the Caucasian than in either of the other varieties of mankind.

The epithet Caucasian, applied to this branch of the human family, is derived from the high moun-

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* The facial angle is formed by the meeting of two lines drawn on the profile of the skull—one of them a line touching the projecting part of the forehead and the gum of the upper jaw, the other connecting the base of the nose and the opening of the ear. The angle formed by the meeting of these lines sometimes amounts in a Caucasian variety of man to 80 degrees and upward; in the other varieties it seldom exceeds 70 degrees; and in the instance of some degraded races is considerably less.

tain range which stretches between the Black and Caspain Seas, and is justified by the fact that the finest specimens of man—physically considered—have in all ages been found in proximity to that region. The perfect forms and external beauty of the Circassian and Georgian people—male and female alike—are well known. The finest types of the white race (mere physical beauty alone being considered) are to be found within the elevated region of the Caucasian isthmus; and it has even been sought to show that the human form degenerates in proportion as its distance thence, in whatsoever direction, is increased. To the westward of the Caucasus (whatever may be the case in other directions), the grace which attends on moral and intellectual dignity is, however, added to that of merely personal beauty.

Considered in reference to color, the Caucasian is the *white* variety of the human family; but the latter epithet must be considered as applicable only in a general sense, for numerous shades of color intervene between the swarthy complexions of the subtropical regions that border on the Mediterranean and the fair skins of the people of Northern and Northwestern Europe. These differences are doubtless in some measure dependent on climate. Yet there must be a well-grounded difference due to other causes, since families of whites dwell during several successive generations within the tropics without acquiring the hue of the Negro, or settle within the western continent without gaining any external resemblance to the copper-colored native of the New World.

The geographical distribution of the Caucasian family in the present day is nearly co-extensive with the land area of the globe; but this family of nations is most numerously developed within the temperate latitudes of the Northern Hemisphere. Western Asia, the European continent (with the exception of a portion in the extreme north), and the northern belt of Africa, are the proper home of the Caucasian tribes. Thence they have colonized nearly every part of the New World, as well as Southern Africa and the more distant regions of Australia and New Zealand, at the opposite side of the globe. Nine-tenths of the population of Europe belong to the Caucasian family of man, the small minority who constitute the exception consisting of the Turks, the Magyars, the Finns, the Laplanders, and the Samoiedes. In Asia, the Caucasian nations form but a minority of its vast population; they include, however, the natives of the Arabian or Semitic stock, the Persians, the Afghans, and perhaps also (such, at least, is the generally received theory) the Hindoos—that is, all the people dwelling to the south of the Himalaya and to the west of the Bay of Bengal. In Africa, the proportion of Caucasians to its population is probably small, though they are spread over the whole of Northern Africa, from the Mediterranean to the southern border of the desert, and the furthest limit of Abyssinia.

In America, the Caucasian family—settling in that part of the world as colonists only within the last three centuries and a half—is fast supplanting the indigenous races, and comprehends two-thirds of the total number of its inhabitants in the present day. Within the temperate latitudes of North America, that is, within the valleys of the Mississippi and St. Lawrence, with the Atlantic seaboard from the Gulf of St. Lawrence southward, the white race is most numerous. Five-sixths of the present population of North America belong, either in whole or in part, to the Caucasian stock.

In the case of Australia, the diminution in the numbers of the native race has been even more rapid than in the case of the Western Continent. The white race, whose date of settlement on the Australian shores is as yet hardly more than three-quarters of a century, now vastly outnumbers the indigenous tribes. In Tasmania, the latter have indeed become extinct. Even in New Zealand, which was peopled by an athletic tribe of savages when Captain Cook visited it less than a century since, the colonial population, planted on its shores within the last forty years, now greatly outnumbers the native tribes, which, moreover, undergo gradual diminution in numerical amount.

The Mongolian variety of man is distinguished by a greater approach to squareness in the shape of the skull (viewed from above), with greater prominence in the cheek-bones—so that lines prolonged from the sides of the face upward meet in a point, giving the entire framework of the head a pyramidal shape. The forehead is comparatively low and slanting; the face and nose broad and flat; the eyes deeply sunk, with the inner corner slanting toward the nose; the complexion of an olive or yellowish-brown color, the hair lank and black, the beard scanty, the stature below that of Europeans, and the frame generally broad, square, and robust, with high shoulders, and the neck thick and strong. These attributes are much less strongly marked in the case of some nations of Mongol parentage than in others, and in the instances of the Magyars, Turks, and Finns—long settled among the Caucasian family—have in great measure disappeared. In point of color, the Mongolian is known as the *yellow* variety of mankind.

The name of Mongolian, applied to this branch of the human family, is derived from the nomad races who peopled the upland plains of Central Asia. It comprehends, besides the Mongols proper, the vast population of China (above a third of the entire human family), together with the Burmese, Siamese, and other inhabitants of the southeastern peninsula of Asia, and the native tribes of the Siberian lowland. The Turks and the Magyars, in Southeastern and Central Europe, the Finns, Samoiedes, and Laplanders, in the extreme north of the same continent, and the Eskimos, in the correspondent latitudes of the New World, belong to the same stock. In all, probably three-fifths of the population of Asia, and more than a half of the population of the globe, are comprehended within this division of mankind.

The Negro, or *black* variety of mankind, is distinguished in general by the elongated form of the skull, combined with a low facial angle. The eyes, as well as the skin, are black; the nose broad, flat, and thick; the cheek-bones prominent; the lips thick; the jaws (especially the lower one) narrow and projecting; the hair woolly; the palms of the hands and the soles of the feet flat; and the forms of the arms and lower extremities generally clumsy and ungraceful. These attributes, however, are very much modified in the case of some members of the Negro race, and they belong in very various degree to the different Negro nations who inhabit the African continent. The black skin, woolly hair, thick lips, and elongated skull are the most striking features of the Negro race.

Africa, to the south of the desert, is the proper home of the Negro race. Tribes of true Negro stock occupy by far the larger portion of that great continent to the southward of the Senegal, the Niger, the basin of Lake Chad, and the highlands of Abyssinia. The Arabs, however, have penetrated Central Africa within the basins of the Niger and Lake Chad, and have been settled for upward of five centuries upon the coasts of Eastern Africa.

The Hottentot and Caffre families, who inhabit the extreme south of the African continent, must be classed as sub-varieties of the Negro stock. The epithet *negroid* is generally applied to these races. But between the Hottentot and Negro types there is a well-marked distinction, and not less so between the Hottentot and the Caffre families. The color of the Hottentot is a dark and yellowish brown; the hair short and frizzled, and distributed over the head in tufts; the stature short. The Caffres are well made and (comparatively to their neighbors of Hottentot race) of muscular frame—their limbs of rounded form, their skin of deep brown color, their hair short, black, and curly, but less woolly than that of the Negro.

The Negro race, through the iniquities of the slave-trade, has been transplanted from Africa to the other side of the Atlantic, and now forms a considerable item in the population of the New World. In North America, the people of pure Negro blood amount, however, to hardly more than a twelfth part of the total population; in South America the proportion is perhaps rather more considerable.

The Malay, or brown family of nations, is distinguished, besides the color of the skin, by lank, coarse, and black hair; with flat faces and obliquely set eyes. Their stature is below the average height either of the Caucasian or the Negro, and the figure generally square and robust.

If the nations of the Malay family are to be referred to one of the three greater divisions, they must be regarded as a sub-variety either of the Mongol or the Negro stock. Proximity of geographical position, with other circumstances, would lead us to prefer the former. The Papuans, however, who inhabit New Guinea and the adjacent islands to the eastward, exhibit many of the characteristics of the Negro type, and the native race of Australia is of the Papuan or Austral-Negro family. There is, in truth, throughout the Australian and Polynesian division of the globe, a well-marked distinction between the brown and the black races. The former, who belong to the true Malay family, comprehend, with the Malays proper (that is, the bulk of the inhabitants of the Malay peninsula and the adjacent islands), the people of Madagascar; also the New Zealanders, and the inhabitants of most of the smaller Polynesian archipelagoes, from the Sandwich Islands on the north to the Society, Navigators, and Friendly groups in the south. The Austral-Negro or Papuan division, on the other hand, includes the native tribes of the Australian continent and the adjacent island of Tasmania (the latter now all but extinct), with the inhabitants of New Guinea, the Louisiade archipelago, New Britain, the Solomon Islands, the New Hebrides, New Caledonia, and the Fiji Islands.

The American, or red variety of mankind, has its home in the two great continents which are together known as the New World. Its distinguishing attributes are a reddish or copper-colored skin, with long, coarse, black hair (which is never crisped like that of the Negro, or curled, as that of the white often is), and scanty beard. The cheek-bones are prominent, but more arched and rounded than those of the Mongol, without being so angular, or projecting at the sides; the orbit generally deep, and the outer angle slightly elevated. In point of temperament, the Indian (as the native inhabitant of the American wilderness is termed) is cold and phlegmatic to an unusual degree, and he manifests an extraordinary insensibility to bodily pain. His bodily senses—of sight, hearing, and smell—are remarkably acute. These, as well as many other attributes of the Indian race, have probably resulted from the conditions of the hunter's life, pursued through many generations.

The above characteristics, however, are exhibited in widely different measure in the case of the numerous native tribes and nations that are found through the whole wide extent of the American continent, though all of them (with the exception of the Eskimos) are classed under the common term Indian. The native races of South America are generally further removed than those of North America from the higher type of the American family, and they become progressively more degraded toward its furthest extremity. Some of the Indian tribes who dwell in the Brazilian forest exhibit a degree of personal ugliness, and a degradation of condition in general, which contrasts strikingly with that of the higher classes of North American Indians, and the native savages of Tierra del Fuego are among the most misshapen and degraded of the human race. In these and some other cases the distortion of feature, and even that observable in the shape of the head, is produced by artificial means, applied in infancy.

The Indian family of nations makes, perhaps, nearer approach to the Mongol than to either of the other two great divisions of mankind, and must be regarded as a sub-variety of that family, if three great varieties only be allowed. The Eskimos, who inhabit the extreme northern shores of the New World, are uniformly regarded as of Mongol origin.

THE HUMAN RACE
—Louis Figuier

WHAT is man? A profound thinker, Cardinal de Bonald, has said: "Man is an intelligence assisted by organs." We would fain adopt this definition, which brings into relief the true attribute of man, intelligence, were it not defective in drawing no sufficient distinction between man and the brute. It is a fact that animals are intelligent and that their intelligence is assisted by organs. But their intelligence is infinitely inferior to that of man. It does not extend beyond the necessities of attack and defence, the power of seeking food, and a small number of affections or passions, whose very limited scope merely extends to material wants. With man, on the other hand, intelligence is of a high order, although its range is limited, and it is often arrested, powerless and mute, before the problems itself proposes. In bodily formation man is an animal, he lives in a material envelope, of which the structure is that of the Mammalia; but he far surpasses the animal in the extent of his intellectual faculties. The definition of man must therefore establish this relation which animals bear to ourselves, and indicate, if possible, the degree which separates them. For this reason we shall define man: *an organized, intelligent being, endowed with the faculty of abstraction.*

By saying that man appeared for the first time upon the globe at the commencement of the Quaternary Period, we establish the fact, which is agreeable to the cosmogony of Moses, that man was formed after the other animals, and that by his advent he crowned the edifice of animal creation.

At the Quaternary Period almost all the animals of our time had already seen the light, and a certain number of animal species existed which were shortly to disappear. When man was created, the mammoth, the great bear, the cave tiger, and the cervus megaceros—animals more bulky, more robust, and more agile than the corresponding species of our time—filled the forests and peopled the plains. The first men were therefore contemporary with the woolly elephant, the cave bear and tiger; they had to contend with these savage phalanxes, as formidable in their number as their strength. Nevertheless, in obedience to the laws of nature, these animals were to disappear from the globe and give place to smaller or different species, while man, persisting in the opposite direction, increased and multiplied, as the Scripture has said, and gradually spread into all inhabitable countries, taking possession of his empire, which daily increased with the progress of his intelligence.

Did man see the light at any one spot of the earth, and at that alone, and is it possible to indicate the region which was, so to say, the cradle of humanity? Or are we to believe that, in the first instance, man appeared in several places at the same time? That he was created and has always remained in the very localities he now inhabits? That the Negro was born in the burning regions of Central Africa, the

Laplander or the Mongolian in the cold regions to which he is now confined?

There is a school of philosophers who assert that man was manifold in his creation, that each type of humanity originated in the region to which it is now attached, and that it was not emigration followed by the action of climate, circumstances, and customs which gave birth to the different races of man. This opinion has been upheld in a work by M. Georges Pouchet, son of the well-known naturalist of Rouen.

If there existed several centres of human creation, they should be indicated, and it should be shown that the men who dwell there nowadays have never been connected with other populations. M. Georges Pouchet preserves prudent silence upon this question; he avoids defining the locus of any one of these supposed multiple creations.

We, on our part, think that man had on the globe one centre of creation, that, fixed in the first instance in a particular region, he has radiated in every direction from that point, and by his wanderings, coupled with the rapid multiplication of his descendants, he has ultimately peopled all the inhabitable regions of the earth.

We need hardly say that animals, like plants, are attached to various localities which they rarely quit with impunity, since they have not the faculty of acclimatizing themselves at will. The elephant lives only in India and in certain parts of Africa; the hippopotamus and giraffe in other countries of the same continent; monkeys exist in very few portions of the globe, and if we consider their different species, we shall find that the place of abode of each species is very limited. For instance, of the larger apes the orang-outang is found only in Borneo and Sumatra, and the gorilla in a small corner of Western Africa. Had man originated in all those places where now his different races are found, he would stand alone as an exception among organized beings.

Reasoning then by induction, that is, applying to man all that we observe to obtain generally among beings living on the surface of the globe, we come to the conclusion that the human species, in common with every vegetable or animal species, had but one centre of creation.

Around the central tableland of Asia are found the three organic and fundamental types of man, that is to say, the white, the yellow, and the black. The black type has been somewhat scattered, although it is still found in the south of Japan, in the Malay Peninsula, in the Andaman Isles, and in the Philippines, at Formosa. The yellow type forms a large portion of the actual population of Asia, and it is well known whence came those white hordes that invaded Europe at times prehistoric and in more recent ages; those conquerors belonged to the Aryan or Persian race, and they came from Central Asia.

Around the central tableland of Asia, we find not only the three fundamental types of the human species, but the three types of human speech. Does not this, therefore, afford ground for presumption, if not actual proof, that man first appeared in this very region which Scripture assigns as the birthplace of the human race?

It is from this central tableland of Asia, radiating so to say around this point of origin, that man has progressively occupied every part of the earth.

Migration commenced at a very early period; the facility with which our species becomes habituated to every climate and accommodates itself to variations of temperature, taken in connection with the nomadic character which distinguished primitive populations, explains to us the displacement of the earlier inhabitants of the earth. Soon, means of navigation, although rude, were added to the power of traveling by land, and man passed from the continent to distant islands, and thus peopled the archipelagoes as well as the mainland. By means of transport, effected in canoes formed from the trunks of trees barely hollowed out, the archipelagoes of the Indian Ocean, and finally Australia, were gradually peopled.

The American continent formed no exception to this law of the invasion of the globe by the emigration of human phalanxes. It is a matter of no great difficulty to pass from Asia to America, across Behring Strait, which is almost always covered with ice, thus permitting of almost a dry passage from one continent to the other. Thus it is that the inhabitants of Northern Asia have found their way into the north of the New World.

This communication of one terrestrial hemisphere with the other is less surprising when we consider what modern historical works have shown, namely, that already about the Tenth Century, which would be nearly 400 years before Christopher Columbus, navigators from the coast of Norway had penetrated to the other hemisphere. The inhabitants of Mexico and Chili possess most authentic historical archives, which prove that a most advanced civilization flourished there at an early period. Gigantic monuments which still remain bear witness to the great antiquity of the civilization of the Incas (Peru) and of the Aztecs (Mexico). It is reasonable to suppose that the inhabitants of America, who thus advanced at a rapid pace in the path of civilization, descended from the hordes of Northern Asia which reached the New World by traversing the ice of Behring Strait.

To explain, therefore, the presence of man upon all parts of the continent, and in the islands, it is not necessary to insist upon the existence of several centres, where our species was created. If popular traditions went to show that all the regions now inhabited have always been occupied by the same people, and that those who are found there have constantly lived in the same places, there might be reason to admit the hypothesis of multiple creations of the human race; but, on the contrary, traditions for the most part teach us that each country has been peopled progressively by means of conquest or emigration. Tradition shows that the nomadic state of existence has universally preceded fixed settlements. It is, therefore, probable that the first men were constantly on the move. A flood of barbarians, coming from Central Asia, overflowed the Roman Empire, and the Vandals penetrated even into Africa. Modern migrations have been conducted on a still vaster scale, for at the present day we find America almost wholly occupied by Europeans; English, Spanish, and other people of the Latin race fill the vast American hemisphere, and the primitive populations of the New World have almost entirely disappeared, annihilated by the iron yoke of the conqueror.

The continent of Asia was peopled little by little by branches of the Aryan race, who came down from the plains of Central Asia, directing their course toward India. As to Africa: that continent received its contingent of population through the Isthmus of Suez, the valley of the Nile, and the coasts of Arabia, by the aid of navigation.

There is therefore nothing to show that humanity had several distinct nuclei. It is clear that man started from one point alone, and that through his power of adapting himself to the most different climates, he has, little by little, covered the whole face of the inhabitable earth.

There is another problem. Did the white, the yellow, and the black man exist from the first moment of the appearance of our species upon the globe, or have we to explain the formation of these three fundamental races by the action of climate, by any special form of nourishment, the result of local resources; in other words, by the action of the soil?

Innumerable dissertations have been written with a view of explaining the origin of these three races, and of connecting them with the climate or the soil. But it must be admitted that the problem is hardly capable of solution. The influence which a warm climate exercises upon the color of the skin is a well-known fact, and it is a matter of common observation that the white European, if transported into the heart of Africa, or carried to the coast of Guinea, transmits to his descendants the brown color which the skin of the Negro possesses, and that in their turn the offspring of Negroes, who have been brought into northern countries, become as they descend paler and paler and end by being white. But the color of the skin is not the only characteristic of a race; the Negro differs from the white, less by the color of his skin than by the structure of the face and cranium, as also by the proportion of his members to one another. Is it not, moreover, a fact that the hottest countries are inhabited by people with white skins? Such, for instance, are the Touaricks of the African Sahara, and the Fellahs of Egypt. On the other hand, men with black faces are found in countries enjoying a mean temperature, as, for instance, the inhabitants of California on the coast of the Pacific Ocean.

We have now another question to consider. Should these white, yellow, or black men, to whom we must add those who are brown and red, all of whom differ one from another in the color of their skin, in height, in their physiognomy, and in their outward appearance, be grouped into different species, or are we to regard them merely as varieties of species—that is to say, *races?*

Buffon, in his chapter upon *man*, a work which we can always read again with admiration and advantage, contents himself with bringing forward the three fundamental types of the human species which have been known from the first under the names of the white, black, and yellow race. But these three

American Reptiles

1 and 2, Water Snakes (*Masticophis*); 3, Horned Toad (*Phrynosoma*); 4, 5, 11, 12, 13, American Toads; 6, Kangaroo Lizard (*Crotaphytus*); 7, Gila Monster (*Heloderma*); 8, Chuckwalla; 9, Harlequin Snake (*Elaps*); 10, Rattlesnake (*Crotalus*)

types in themselves do not exemplify every human physiognomy. The ancient inhabitants of America, commonly known as the Red-Skins, are entirely overlooked in this classification, and the distinction between the Negro and the white man can not always be easily pointed out, for in Africa the Abyssinians, the Egyptians, and many others, in America the Californians, and in Asia the Hindoos, Malays, and Javanese are neither white nor black.

Blumenbach, the most profound anthropologist of the last century, and author of the first actual treatise upon the natural history of man, distinguished in his Latin work, *De Homine,* five races of men, the Caucasian, Mongolian, Ethiopian, Malay, and American. Another anthropologist, Prochaska, adopted the divisions pointed out by Blumenbach, but united under the name of the *white race*, Blumenbach's Caucasian and Mongolian groups, and added the *Hindoo race*.

The eloquent naturalist Lacépède, in his *Histoire naturelle de l'Homme*, added to the races admitted by Blumenbach the *hyperborean race*, comprising the inhabitants of the northern portion of the globe in either continent.

Cuvier fell back upon Buffon's division, admitting only the white, black, and yellow races, from which he simply derived the *Malay* and *American* races.

A naturalist of renown, Virey, author of *l'Histoire naturelle du Genre humain, l'Histoire naturelle de la Femme*, and of many other clever productions upon natural history and particularly anthropology, gave much attention to the classification of the human races. But he was not favorable to the unity of our species, being led to entertain the opinion that the human species was twofold. This was the starting point of an erroneous deviation in the ideas of naturalists who wrote after Virey. We find Bory de Saint Vincent admitting as many as fifteen species of men, and another naturalist, Desmoulins, doubtless influenced by a feeling of emulation, distinguished sixteen human species, which, moreover, were not the same as those admitted by Bory de Saint Vincent.

This course of classification might have been followed to a much greater extent, for the differences among men are so great that if strict rule is not adhered to it is impossible to fix any limit to species. Unless therefore the principle of unity has been fully conceded at starting, the investigation may result in the admission of a truly indefinite quantity.

This is the principle which pervades the writings of the most learned of all the anthropologists of our age, Dr. Pritchard, author of a *Natural History of Man*, which in the original text formed ten volumes, but of which the French language possesses but a very incomplete translation.

Dr. Pritchard holds that all people of the earth belong to the same species; he is a partisan of the unity of the human species, but is not satisfied with any of the classifications already proposed, and which were founded upon organic characteristics. He, in fact, entirely alters the aspect of the ordinary classifications which are to be met with in natural history. He commences by pointing out three families, which, he asserts, were in history the first human occupants of the earth: namely, the *Aryan*, *Semitic*, and *Egyptian*. Having described these three families, Pritchard passes to the people who, as he says, radiated in various directions from the regions inhabited by them, and proceeded to occupy the entire globe.

This mode of classification, as we have pointed out, leaves the beaten track trodden by other natural historians. For this reason it has not found favor among modern anthropologists, and this disfavor has reacted upon the work itself, which, notwithstanding, is the most complete and exact of all that we possess upon man. Although it has been adopted by no other author, Pritchard's classification of the human race appears to us to be the most sound in principle.

The classification of the human race which we propose to follow, modifying it where in our opinion it may appear to be necessary, is due to a Belgian naturalist, M. d'Omalius d'Halloy. It acknowledges five races of men: the white, black, yellow, brown, and red.

When we examine the form and relative size of the brain in ascending the series of mammiferous animals, we find that this organ increases in volume, and progresses, so to say, toward the superior characteristics which it is to display in the human species. The brain increases in importance from the zoophyte to the ape. But, in comparing the brain of the ape with that of man, an important difference becomes at once apparent. The brain of the gorilla, orang-outang, or chimpanzee, which are the apes that bear the greatest resemblance to man, and which for that reason are designated *anthropomorphous* apes, is very much smaller than that of man.

The senses, taken individually, are not more developed in man than they are in certain animals; but in man they are characterized by their harmony, their perfect equilibrium, and their admirable appropriation to a common end. Man, it will at once be admitted, is not so keen of sight as the eagle, nor so subtle of hearing as the hare, nor does he possess the wonderful scent of the dog. His skin is far from being as fine and impressionable as that which covers the wing of a bat. But, while among animals, one sense always predominates to the disadvantage of the rest, and the individual is thus forced to adopt a mode of existence which works hand in hand with the development of this sense, with man, all the senses possess almost equal delicacy, and the harmony of their association makes up for what may be wanting in individual power.

Man is certainly better off, as regards the sense of sight, than a large majority of animals. Instead of being placed upon different sides of his head, looking in opposite directions, and receiving two images which can not possibly be alike, his eyes are directed forward, and regard similar objects, by which means the impression is doubled.

The sense of touch in man reaches a degree of perfection which it does not attain in animals. How marvelous is the sense of touch when exercised by applying the extremities of the fingers, the part of the body the best suited to this function, and how much more wonderful is the organ called the hand, which applies itself in so admirable a manner to the most different surfaces whose extent, form, or qualities we wish to ascertain!

"Man alone," says Galen, "is furnished with hands, as he alone is a participator in wisdom. The hand is a most marvelous instrument, and one most admirably adapted to his nature. Remove his hand, and man can no longer exist. By its means he is prepared for defence or attack, for peace or war. What need has he of horns or talons? With his hand, he grasps the sword and lance, he fashions iron and steel. While with horns, teeth, and talons animals can only attack or defend at close quarters, man is able to project from afar the instruments with which he is armed. Shot from his hand, the feathered arrow reaches at a great distance the heart of an enemy, or stops the flight of a passing bird. Although man is less agile than the horse and the deer, yet he mounts the horse, guides him, and thus successfully hunts the deer. He is naked and feeble, yet his hand procures him a covering of iron and steel. His body is unprotected against the inclemencies of climate, yet his hand finds him a convenient abode, and furnishes him with clothing. By the use of his hand, he gains dominion and mastery over all that lives upon the earth, in the air, or in the depths of the sea.

The sense of hearing, without attaining in man the perfection which it reaches in certain animals, is nevertheless of great delicacy, and becomes an infinite resource of instruction and pure enjoyment. Not only are differences of intonation, intensity, and timbre recognized by our ear, but the most delicate shades of rhythm and tone, the relations of simultaneous and successive sounds which give the sentiment of melody and harmony, are appreciated, and furnish us with the first and most natural of the arts —music.

Let us now pass to the bony portion of the human body, and consider first of all the head. The head is shared by two regions, the cranium and the face. The predominance of either of these regions over the other depends upon the development of the organs which belong to each.

The cranium contains the cerebral mass, that is, the seat of the intellect; the face is occupied by the organs appertaining to the principal senses. In animals, the face greatly exceeds the cranium in extent; the reverse is, however, the case with man. It is but rarely that with him the face assumes importance at the expense of the cranium—in other words, that the jaws become elongated, and give to the human face the aspect of a brute.

There is in the human face an anatomical characteristic of greater importance than any taken from the elongation of the cranium; that is, the projection forward, or the uprightness of the jaws. The term *prognathism* (from πρὸ, forward, and γνάθος, jaw) is applied to this jutting forward of the teeth and jaws, and *orthognathism* (from ὀρθὸς, straight, γηάθς, jaw) to the latter arrangement.

It was long admitted that prognathism, or projection of the jaws, was peculiar to the Negro race. But this opinion has been forced to yield to the discovery that projecting jaws exist among people in no way connected with the Negro. In the midst of white populations this characteristic is frequently met with; it is occasionally found among the English, and is by no means rare at Paris, especially among women. Prognathism would appear to be characteristic of a small European race dwelling to the south of the Baltic Sea, the Esthonians, and which itself is but the residue of the *primitive Mongolian* race. It is probably the mixture of Esthonian blood with that of the inhabitants of Central Europe, which causes the appearance in our large cities of individuals whose faces are prognathous.

We can not close our remarks upon the face without speaking of a curious relation between it and the cranium, which has been much abused; we allude to the *facial angle*. By *facial angle* is meant the angle which results from the union of two lines, one of which touches the forehead, the other of which, drawn from the orifice of the ear, meets the former line at the extremity of the front teeth.

The Dutch anatomist Camper, after having compared Greek and Roman statues, or medals of either nationality, assumed that the cause of the intellectual superiority which distinguished Greek from Roman physiognomies was to be found in the fact that, with the Greeks, the facial angle is larger than in Roman heads. Starting with this observation, Camper pursued his inquiries until it occurred to him to advance the theory that the increase of the facial angle may be taken in the human race as a sign of superior intelligence.

This observation was correct, insomuch as it separated men from apes, and carrion birds from other birds. But its application to different varieties of men, as a measure of their various degrees of intelligence, was a pretension doomed to be sacrificed to future investigations. Dr. Jacquart, assistant naturalist in the Museum of Natural History at Paris, calling to his aid an instrument he invented, by which the facial angle is rapidly measured, has, in our day, made numerous studies of the facial angle of human beings. M. Jacquart found that this angle can not be taken as a measure of intelligence, for he observed it to be a right angle in individuals who, with respect to intelligence, were in no way superior to others whose facial angle was much smaller.

Erect carriage is another of the characteristics which distinguish the human species from all other animals, including the ape, by whom this position is but rarely assumed, and then accidentally and unnaturally.

Everything in the human skeleton is calculated to ensure a vertical posture. In the first place, the head articulates with the vertebral column at a point so situated that, when this vertebral column is erect, the head, by means of its own weight, remains supported in equilibrium. Besides this, the shape of the head, the direction of the face, the position of the eye, and the form of the nostrils all require that man should walk erect on two feet.

J. J. Rousseau was, therefore, very far from right when he contended that man was born to go on all fours.

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