

rated by pressure. Its price was recently about 36s. per cwt. The price of cotton seed oil was about 23s. per cwt. The price of lard was about 47s. per cwt. It will thus be seen that there would be a large margin of profit if a compound consisting of 50 or 60 per cent. of the cheaper cotton seed oil and beef stearin could be sold at the price of genuine lard; and this is probably the clue to the true explanation of the adulteration.

I do not enter into the question as to whether cotton seed oil and beef stearin are better or worse than pure lard. I do say, however, that such a compound ought to be sold under its proper description, and not passed off on the public as pure lard. When a purchaser wants and asks for lard he should be able to get it, and not be supplied with another and a cheaper article. The selling of such adulterated lard is also a serious injury to fair and legitimate lard packers who will only supply pure lard, but who are undersold by the makers of the adulterated lard.

To detect cotton seed oil and beef stearin in lard, and to form an estimate of the quantity, the following tests are chiefly relied on: Some form of the nitrate of silver test for cotton seed oil, the microscopical appearance of the crystals formed from an ethereal solution of the lard to detect beef stearin, the iodine absorption equivalent, and the specific gravity. Useful information is also afforded by an examination of the color, taste, smell, and consistency of the lard.

The Nitrate of Silver Test.—This is based on the reducing action of cotton seed oil upon nitrate of silver, the reduced silver imparting a color to the lard. I have been unable to obtain constant or trustworthy results with this test as applied by Becchi (see *Analyst* of September, 1887), who I believe first proposed it, nor have I been more successful with the more complicated modification of Milliau (see *Analyst* of May, 1888), which consists in applying the test to the fatty acids separated from the lard, nor with the several other modifications of this test which have been published. I obtain, however, very regular and certain results by adding an alcoholic solution of nitrate of silver to an ethereal solution of the lard. The method is as follows: 40 drops of the melted lard are placed in a test tube, and dissolved in 10 c. c. of ether, and to the solution 2 c. c. of an alcoholic solution of nitrate of silver (1 of nitrate of silver to 100 of alcohol) are added. The tube and its contents are left to stand for five or six hours in a place protected from light. If the lard contains cotton seed oil, the silver is reduced and imparts a maroon color to the solution—the depth of the color depending on the proportion of cotton seed oil the sample contains. By comparing this color with the colors produced in solutions of pure lard to which known percentages of cotton seed oil have been added, a close approximation to the amount of cotton seed oil in the sample can be obtained. Five per cent. of cotton seed oil in a lard can be readily detected by this method.

Test for Beef Stearin.—The positive evidence of the presence of this substance in lard is best obtained by examining under a microscope the crystals formed from an ethereal solution of the lard, as proposed by Dr. Belfield, of Chicago, and described in the *Analyst* of April last. For this purpose I use the ethereal solution of the lard mentioned in the last paragraph. Should crystals not form in the cooled solution, the cork of the tube is removed and a loose plug of cotton wool is substituted. The solution is then left to evaporate spontaneously until crystals form. It is sometimes necessary to redissolve the crystals, if they have been formed rapidly, by warming the solution, and sometimes adding a little more ether, so as to obtain crystals which have been slowly formed. Some of the crystals are then removed by a pipette, placed under a microscopic slide, and examined. The crystals of beef stearin form curved tufts somewhat of the shape of the short tail of a horse. The terminals should be pointed and hair like. Lard crystals are usually found in oblong plates, occasionally radiated, and have oblique terminals.

The Iodine Absorption Test.—This was first described by Hubl, whose method is given in the *Journ. Soc. Chem. Ind.*, 1881, page 641. According to my experience with lards of known purity, I find the iodine absorption equivalent of pure lard when tested by Hubl's method to vary from 57 to 63 per cent., and cotton seed oil to vary from 105 to 116 per cent. Were the lards to be examined for only mixtures of cotton seed oil and lard, it would be easy to arrive at a fairly close approximation to the actual amounts of each present from this test alone.

This, however, is never the case, as probably all lards which contain cotton seed oil have also had beef stearin added to make the mixture of a suitable consistency. Beef stearin has an iodine absorption of from 23 to 28 per cent., while beef fat, which may also have been used as an adulterant, has an iodine absorption of about 41 per cent. This, unfortunately, complicates the calculation of percentage amounts of impurity from the iodine absorption equivalents. Most of the adulterated samples, however, have hitherto contained cotton seed oil in such large quantity, and the iodine equivalent is so high, that a very substantial adulteration can be certified to without taking into account the effect of the beef stearin.

When, however, the amount of cotton seed oil is ascertained by the nitrate of silver test, a near approach to the amount of beef stearin also present can be calculated from the iodine absorption, after making allowance for the influence of the known quantity of cotton seed oil. If the lard is found to be a mixture of lard and beef stearin or beef fat without cotton seed oil, the calculation of the proportions of each is simplified; but as at present there are no known means of distinguishing beef fat from beef stearin in lard, it is necessary to calculate from the lower iodine absorption of beef stearin, and thus the amount of beef stearin may be understated. If the iodine absorption of such a lard be found to be 42 per cent., it will be safe to conclude that the lard contains one-half beef stearin and one-half lard, calculating the pure lard iodine equivalent at 61 and that of the beef stearin at 23 per cent., as $61 + 23 = 84 \div 2 = 42$.

The Specific Gravity Test is also a useful corroboration of the other tests, for cotton seed oil is higher in density than lard or stearin. It is customary to take the gravity at a temperature of 210° Fah. as compared with water at 60° Fah., and this is best done with a Westphal balance. At 210° Fah. pure lard has a gravity varying from 860 to 861, cotton seed oil is 868, and

beef stearin 857. Lard adulterated with cotton seed oil is usually comparatively high in gravity. Some adulterated samples which have come under my notice have had a gravity of 863.5.

Mr. Jones, of Wolverhampton, has suggested in the *Analyst* for September last a qualitative test for cotton seed oil based on the stiffening effect which such oil imparts to a mixture of lard when sulphur chloride is added to it. This is a useful corroborative test.

Should the lard contain water, this is readily ascertained by the crackling effect produced when a portion of the lard is thrown on a red hot fire or into a red hot platinum dish. Its amount is determined by drying at 212° Fah. a known weight of the lard in a flat-bottomed straight-sided dish until it ceases to lose weight.

It is satisfactory to be able to state that in this district, at any rate, the cotton seed oil adulteration of lard is now seldom or never met with. This is owing to the prompt action which the authorities have taken in the matter, and also no doubt to the desire of wholesale dealers to avoid purchasing such lard now that they know of the existence of the adulteration. There are still many samples to be met with which contain very large admixtures of beef stearin or beef fat.—*Journ. Chem. Ind.*

STRUCTURE, ORIGIN, AND DISTRIBUTION OF CORAL REEFS AND ISLANDS.*

By Dr. JOHN MURRAY.

THE picturesque beauty of the coral atoll, seated amid a waste of troubled waters, with its circlet of living green, its quiet, placid lagoon, and its marvelous submarine zoological gardens, has long been celebrated in the descriptions of voyagers to tropical seas. The attempt to arrive at a correct explanation of the general and characteristic form and features of these reefs and islands has, for an equally long period of time, exercised the ingenuity of thoughtful men.

Coral reefs are the most gigantic and remarkable organic accumulations on the face of the earth. They are met with in certain tropical regions, and are huge masses of carbonate of lime, secreted from ocean waters by myriads of marine organisms. While the great bulk of the reef consists of dead corals, skeletons, and shells, the outer surface is clothed with a living mantle of plants and animals. This is especially the case on the outer and seaward face of the reef, where there are at all times myriads upon myriads of outstretched and hungry mouths, and not the least interesting questions connected with a coral reef are those relating to how these hungry mouths are satisfied.

It is to the power of these organisms of secreting carbonate of lime from sea water—building up and out generation after generation on their dead selves—that the coral reef owes its origin. So wonderful and unique is the result, that combination for a definite end has sometimes been attributed to these reef builders.

There is, however, another process ever at work in the ocean, in a sense antagonistic to that of secretion of carbonate of lime by organisms, which has much to do in fashioning the more characteristic features of coral reefs. This is the solution of all dead carbonate of lime shells, skeletons, and calcareous debris, wherever these are exposed to the action of sea water. As soon as life loses its hold on the coral structures, and wherever these dead carbonate of lime remains are unprotected by rapid accumulation or crystalline depositions, they are silently, surely, and steadily removed in solution. This appears to be one of the best established oceanographical facts, and any theories concerning the general economy of the ocean which fail to take account of this universal agency are most likely to be at fault. We know something about the rate of solution, probably more than we do about the rate of growth and secretion of carbonate of lime by the coral polyps.

It has been shown that the rate of solution varies with temperature, with pressure, and with the amount of carbonic acid present in the water. It is on the play of these two opposing forces—the one vital and the other chemical—and their varying activity in different regions and under different circumstances, that we rely for the explanation of many oceanographical phenomena, especially many of those connected with oceanic deposits and coral reefs. In some regions there may be more growth, secretion, and deposition of shell and coral materials than solution by sea water, and then there results the formation of coral reefs and vast calcareous deposits at the bottom of the ocean. There may be an almost exact balance between these processes. And again there may be more solution than secretion, as, for instance, in the red clay areas, which occupy the deepest parts of the ocean, and in some coral reef lagoons.

What is the nature of the foundations of these coral islands, surrounded as they sometimes are by an ocean miles in depth? Why have some elongated reefs, no lagoons? Why have most of the lagoons of the smaller atolls been filled up? Why is the circle of land or reef in the perfect atolls only, at most, a few hundred yards in diameter? What is the origin of the lagoon? What relation exists between the depth of the lagoon, its area, and the depth of the water beyond the outer reef? How has the dry land of these islands been formed, provided with a soil, a fauna, and a flora? These appear to be the chief questions that demand an answer from any theory of coral island formation.

These coral formations are essentially structures belonging to the great oceans and ocean basins. They are dots of land within the oceanic areas that might be compared or contrasted with the small salt lakes which are scattered over the surface of the continental lands. A rapid survey of some of the more general phenomena of the great oceans may, then, lead to a better appreciation of the problems connected with coral reefs.

The great ocean basins occupy over two-thirds of the earth's surface, and have a mean depth of over two miles. The central portions of these basins, called the abyssal regions, occupy about one-half of the earth's surface, and have a mean depression below the general level of the continents of over three miles. The abyssal regions are vast undulating plains, sometimes rising to less than two miles from the surface of the sea, and again sinking to four or five miles beneath it. Volcanic cones rise singly or in clusters from these great submerged plains. When they shoot above the level of the

sea, they form single islands, like Ascension and St. Paul's Rocks, or groups, like the Azores, the Sandwich, the Fiji, and the Society Islands. As might have been expected, there are many more of these cones hidden beneath the waves than rise above them. When the Challenger sounded along the west coast of Africa, there was no suspicion that between her stations she was sailing over submerged cones. Since then, however, the soundings of telegraph ships have correctly mapped out no less than seven of these peaks between the latitude of Lisbon and the island of Teneriffe. The depths on the summits of these vary from 12 to 500 fathoms. On one of them, at 400 fathoms, two species of coral (*Lophelia prolixa* and *Amphipolia oculata*) were growing luxuriantly. Throughout the ocean basins about 300 such submarine cones, rising from great depths up to within depths of from 500 to 10 fathoms from the surface, are already known, or indicated by soundings.

All the physical agencies at work above the lower limit of wave action tend to wear away and level down these cones, and thus to form banks. Graham's Island, thrown up in the Mediterranean in 1831, was 200 ft. in height and three miles in circumference, and was washed away in a year or two. The bank left on the spot, at first very shallow, has now 24 ft. of water over it. Instances similar to this historical example must often have happened in the great ocean basins. Again, the same agencies produce wide banks around volcanic islands by washing away and spreading out the materials of the softer rocks. Such banks, with depths of less than 60 fathoms, are found extending many miles seaward around some volcanic islands.

On the other hand, all the deeply submerged summits are continually being built up to the lower limit of wave action by the accumulation of the remains of animals which live on them and by the fall of shells upon them from the surface waters. In the Solomon Islands, Dr. Brougham Guppy has shown that there are upraised coral islands with central volcanic cones covered with thick layers of marine deposits. Christmas Island, in the Indian Ocean, is another instance, and similar deposits must now be forming over hundreds of submerged mountains. In this way are foundations prepared for the true reef-building species, which only flourish in the shallower depths.

The bulk of the water of the ocean has a very low temperature; it is ice-cold at the bottom, even under the equator, but on the surface within the tropics there is a relatively thin film of warm water, with a temperature of from 70° to 84° F. This film of warm water is much deeper toward the western parts of the Atlantic and Pacific than it is in the eastern, the reason for this being that the trade winds, which blow continually from the east, carry all the warm surface water to the westward, and draw up the cold water from beneath along the western shores of Africa and America to supply the place of that driven westward at the surface. Consequently, there is, at times, a very low temperature, and a great annual range of temperature, along these western shores. This is more clearly shown by the temperatures at 50 and 100 fathoms than by those at the surface. There are no coral reefs along the western shores of Africa and South America, a circumstance evidently connected with the low temperature, wide range, and, more directly, with the food supply consequent on these conditions. It appears to be a confirmation of this view that, on the eastern shores of Africa, about Cape Guardafui, from off which the southwest monsoon blows for several months in the year, cold water is also drawn to the surface, and there, likewise, are no coral reefs, though they flourish to the north and south of this region.

Coral reefs flourish in mid-ocean and along the eastern shores of the continents, or wherever the coasts are bathed by the warmest and purest currents of water coming directly from the open sea. If we except Bermuda and one or two other outlying reefs, where the temperature may occasionally fall to 66° or 64° F., it may be said that reefs are never found where the surface temperature of the water, at any time of the year, sinks below 70° F., and where the annual range is greater than 12° F. In typical coral reef regions, however, the temperature is higher and the range much less.

The food supply of the coral reef is derived from pelagic oceanic organisms, which exist in the greatest variety and abundance in the surface and sub-surface waters of the ocean. These consist of myriads of Algæ, Rhizopods, Infusorians, Medusæ, Annelids, Mollusks, Crustaceans, Ascidians, and fishes. A very large number of these creatures, within the tropics, secrete carbonate of lime from the ocean to form their shells and skeletons, which, falling to the bottom after death, form the vast oceanic deposits known as Pteropod and Globigerina oozes. It falling to the bottom, they carry down some of the organic matter that composed their living bodies, and thus are the animals which live on the floor of the ocean chiefly supplied with food. Here it may be remarked, incidentally, that the abundance of life at depths of even over two miles is very great. Our small dredges sometimes bring up over sixty species and hundreds of specimens in one haul—of invertebrates and fishes, exclusive of the Protozoa. The pelagic organisms above mentioned oscillate from the surface down to about 80 or 100 fathoms, probably that stratum of the ocean affected by sunlight, and they apparently descend further in regions where the stratum of warm water has a greater depth. Many of the forms rise to the surface in the evening and during calms, and sink again in sunlight and during stormy weather. It is in the evening and when it is calm that this swarming life is most vividly forced on the attention by gorgeous phosphorescent displays. The lime-secreting organisms, like Coccospores and Rhabdospheres, Foraminifera, Pteropods, and other mollusks, are much more abundant, both in species and individuals, in the warmest and saltiest waters than elsewhere. I have estimated, from tow-net experiments, that at least 16 tons of carbonate of lime, in the form of these shells, exist in a mass of the ocean, in coral reef regions, one mile square by 100 fathoms in depth. If we take this estimate, which I consider much below the reality, and suppose one-sixteenth of these organisms to die and fall to the bottom each day, then they would take between 400 and 500 years to form a deposit one inch in thickness. I give this calculation more to indicate a method than to give even the roughest approximation to a rate of accumulation of deposits. The experiments were too few to warrant any definite deductions.

* Lecture delivered by Dr. John Murray at the Royal Institution on Friday, March 16, 1888. Recently revised by the author.—*Nature*.

The great oceanic currents, moving westward at the rate of several miles an hour, bear these shoals of pelagic organisms on to the face of the reef, where millions of greedy mouths are ready and eager to receive them. The corals and other organisms situated on the outer and windward side of the reef receive the first and best supply; they are thus endowed with a greater amount of energy, and grow faster and more luxuriantly there than on other portions of the reef. The depth at which there is the most constant supply of this food is several fathoms beneath the surface, and there, too, the corals are found in most vigorous growth. It is only a relatively small quantity of this pelagic food that enters the lagoon, the corals that there struggle on in patches being largely supplied with the means of existence from the larvæ of reef-building animals.

So many observations were made during the Challenger expedition on the pelagic fauna inside and outside reefs that there is little, if any, doubt in my mind that the food supply is a most important factor in relation to the growth of corals in the different portions of a reef. Actual observations were made on the feeding of corals at a good many places, as well as numerous observations on the stomach contents. These observations have been confirmed by Alexander Agassiz.

It is as yet impossible to state in what form the lime which is secreted as carbonate in such enormous quantities by marine organisms exists in the ocean.

Dana, in "Coral and Coral Islands," considers it "unnecessary to inquire whether the lime in sea water exists as carbonate or sulphate, or whether chloride of calcium takes the place of these. The powers of life may take from the element present whatever results the function of the animal requires."

In connection with this question an interesting series of experiments are being conducted at the Scottish Marine Station, Granton, which go far to prove that the above hypothesis is correct.

The following table shows the average composition of sea water salts, the acids and bases being combined in the way usually adopted by chemists:

Average Composition of Sea Salt.

Chloride of sodium	77.758
Chloride of magnesium	10.878
Sulphate of magnesium	4.737
Sulphate of lime	3.600
Sulphate of potash	2.465
Bromide of magnesium	0.217
Carbonate of lime	0.343
	100.000

In the actual ocean water there are probably traces of every known element, and it is impossible to say what is the precise amount of the respective chlorides, sulphates, and carbonates present. Theoretically, every base may be combined with every acid, and the whole solution must be in a continual state of flux as to its internal composition. While the quantity of sea salts in a given volume of water varies with position, yet it has been shown by hundreds of analyses that the actual ratio of acids and bases—that is, the ratio of the constituents of sea salts—is constant in waters from all regions and depths, with one very significant exception—that of lime—which is present in slightly greater proportion in deep water.

The total amount of calcium in a cubic mile of sea water is estimated at nearly 2,000,000 tons. The amount of the same element present in a cubic mile of river water is nearly 150,000 tons. At the rate at which rivers carry down water from the land, it is estimated that it would take 680,000 years to pour into the ocean an amount of calcium equal to that now held by the ocean in solution.

The amount of calcium existing in the 40,000,000 square miles of the typical calcareous deposits of the ocean exceeds, however, that at present held in solution if we merely take them to have an average thickness of 30 ft.; and from this calculation we might say that, if the secretion and solution of lime in the other regions of the ocean be exactly balanced, and the calcium in the ocean remain always constant, those calcareous deposits of the thickness indicated would require between 600,000 and 700,000 years to accumulate. There is good evidence, however, that the rate of accumulation is much more rapid in some positions.

The lime thus carried down to the sea is originally derived from the decomposition of anhydrous minerals, and comes from the land in the form of carbonate, phosphate, and sulphate of lime—the carbonate being in the greatest abundance in river water. On the other hand, the sulphate of lime very greatly predominates in sea water, the carbonates being present in small quantity. We are not in a position to say whether or not the coral polyps take the whole of the material for their skeletons from the carbonates, as is generally believed, or indeed to say what changes take place during the progress of secretion by organisms.

In the greatest depths of the Pacific coral seas there is striking evidence of the solvent power of ocean water. Our dredges bring up from a depth of three or four miles over a hundred earbones of whales and remnants of the dense Ziphioid beaks, but all the larger and more areolar bones of these immense animals have been almost entirely removed by solution. In a single haul there may also be many hundreds of sharks' teeth, some of them larger than the fossil *Carcharedon* teeth, but all that remains of them is the hard dentine. None of the numerous calcareous surface shells reach the bottom, although they are quite as abundant over the red clay areas as over those shallower areas where they form Globigerina and Pteropod deposits. In consequence of the small amount of detrital material reaching these abyssal areas distant from continents, cosmic metallic spherules, manganese nodules, highly altered volcanic fragments, and zeolitic minerals are there found in great numbers. Almost all these things are found occasionally in the other regions of the ocean's bed, but their presence is generally masked by the accumulation of other matters. In some regions Radiolarian and Diatom remains are found in the greatest depths, and they too are subject to the solvent power of sea water, but to a much less extent than carbonate of lime shells.

As we ascend to shallower waters, a few fragments of the thicker-shelled specimens are met with at first; with lesser depths the carbonate of lime shells increase in number, until in the shallower deposits the remains

of Pteropods, Heteropods, and the most delicate larval shells are present in the deposit at the bottom. This gradation in the appearance of the shells can be well seen in a series of soundings at different depths around a volcanic cone, such as has been described as forming the base of a coral atoll. There is no known way of accounting for this vertical distribution of these dead shells except by admitting that they have been dissolved away in sinking through the deeper strata of water, or shortly after reaching the bottom; indeed, an examination of the shells themselves almost shows the process in operation. It is rare to find any trace of fish-bones in deposits other than the otoliths.

These considerations, as well as numerous experiments in the laboratory, show that everywhere in the ocean dead or amorphous carbonate of lime structures quickly disappear wherever they are exposed to the action of sea water, and in investigating the evolution of the general features of coral reefs it is as necessary to take cognizance of this fact as of the secretion of carbonate of lime by organisms. At the same time, too much stress cannot be laid upon the fact that carbonate of lime, although markedly soluble in sea water in the amorphous form in which it exists in connection with (organic) life, becomes practically insoluble when after the death of the secreting animal it assumes the crystalline state.

In a paper read before the Royal Society of Edinburgh, embodying some of the results of his investigations on the solubility of carbonate of lime under different forms in sea water, Mr. Irvine remarks, "It is due to this molecular change that coral deposits, shells, and calcareous plants are able to accumulate in the ocean, ultimately to form beds of limestone rocks."

The first stage, then, in the history of a coral island is the preparation of a suitable foundation on the submerged volcanic cones or along the shores of a volcanic island or the borders of a continent. In the case of the atoll the cone may have been reduced below the level of the sea by the waves and atmospheric influences, or built up to the lower limit of breaker action by the vast accumulation of organisms on its summit.

A time comes, however, should the peak be situated in a region where the temperature is sufficiently high, and the surface currents contain a suitable quality of food, that the reef builders fix themselves on the bank. The massive structure which they secrete from ocean water enables them to build up and maintain their position in the very face of ocean currents, of breakers, of the overwhelming and outrageous sea.*

"Coral" with the sailor or marine surveyor is usually any carbonate of lime shell or skeleton or their broken down parts. "Coral" is used by the naturalist in a much more restricted sense: he limits the term to animals classed as Madreporæ, Hydrocorallines, and Alcyonarians. The animals belonging to the first two of these orders comprise those included under the vague term of reef corals. Besides these, however, very many other classes of animals contribute to the building up of coral reefs and islands—such as Foraminifera, Sponges, Polyzoa, Annelids, Echinoderms, and Calcareous Algæ. The relative proportions of these different organisms in a reef vary with the region, with the depth, and with the temperature, but members of what are known under the term of reef corals appear always to predominate.

The animals of the true reef-building species resemble the common sea anemones in structure and size; the individual polyps may vary from the eighth of an inch in diameter to over a foot. Some of the structures built by colonies may exceed 20 feet in diameter.

There may be great variety in the appearance of submerged reefs as they rise from banks of a different nature, form, and extent, as, indeed, was pointed out long ago by Chamisso. There may be differences due also to the kinds and abundance of deep sea animals living on such banks, as well as differences due to currents, temperature, and other meteorological conditions.

From the very first the plantations situated on the outer edge will have the advantage, from the more abundant supply of food and the absence of sand in the water, which last more or less injuriously affects those placed toward the interior. Chamisso attributed the existence of the lagoon to the more vigorous growth of the peripherally situated corals of a reef, as compared with those placed toward the middle, and in this he was to a large extent right, but the symmetrical form of the completed atoll is chiefly due to the solution of the dead carbonate of lime structures.

The Great Chagos Bank illustrates the irregular way in which such a large bank of coral plantations approaches the surface. When these, however, reach the surface, they assume slowly a more regular outline, those on the outer edge coalesce, and ultimately form a complete ring of coral reef, and the lagoon becomes gradually cleared of its coral patches or islands, for, as the atoll becomes more perfect, the conditions of life within the lagoon become less and less favorable, and a larger quantity of dead coral is removed in solution.

The coral atoll varies greatly in size and form; it is usually more or less circular, horse shoe shaped, and may be one or over fifty miles in diameter. The breakers spend their fury on the outer edge, and produce what is known as the broad shore platform; but within, trees descend to the very shore of the lagoon, where there is quiet water, and a ship may often enter on the lee side of the atoll and find safe anchorage.

In this connection it is important to bear in mind the relation which exists between the periphery and the superficial area of the lagoon in atolls of different sizes. If the coral plantations which rise from the top of a submerged mountain have an area of one square mile, then on reaching the surface of the waves there will be a shallow depression in the center, owing to the more rapid growth of the outer edge. Such an atoll will have, if it be a square, four miles of outer reef for the supply of coral sand and other debris, and these being washed and blown into the one square mile of shallow lagoon, it is likely to become filled up, the result being a small island with dry lagoon, in which may be found deposits of sulphate of lime, magnesium and phosphatic rocks, and guano—all these testifying to the great age of the island and absence of subsidence.

* Dr. Brougham Guppy says, "History can afford us no clew to the first appearance or the age of reefs; yet in the myths of the Pacific Islanders we find that the savage inhabitants of these regions regard the history of a coral atoll as commencing with the submerged shoal, which through the agency of God-like heroes is brought up by their fish hooks to the surface."—Paper, Vict. Inst.

in the region. It is only atolls with a diameter of less than two miles that thus become filled up. In other and larger plantations, rising from a more extensive bank, the conditions are very different. In this larger atoll—say four miles square—there is now only one mile of outer reef to each square mile of lagoon, instead of four miles of outer reef to the one square mile of lagoon in the smaller atoll. Only one-fourth of the detrital matter and food enters the larger lagoon, from the outside, per square mile of lagoon, and hence there is proportionately less living coral, the solvent agencies predominate, and the lagoon is widened and deepened. Growing seaward on the outer face and dissolving away in the lagoon, the whole expands after the manner of a fairy ring, and the ribbon of reef or land can never in consequence increase beyond a half or three-quarters of a mile in width, it being usually much less. I have recently made a very careful comparison of the latest Admiralty survey of the lagoon of Diego Garcia with the one made many years ago, and the result appears to me to indicate that the area of the lagoon has considerably increased in the interval, and the average depth is a little greater than formerly, although shallower in some places.

Atolls may occur far away from any other land, but it more frequently happens that they are arranged in linear groups, in this respect resembling volcanic islands. Extensive banks may be crowded with small atolls, like the Northern Maldives; or a bank may be occupied by one great and perfect atoll twenty to forty miles in diameter, like some of the Southern Maldives and the Paumotus. In some instances the large atolls appear to have resulted from the growth and coalescence of the smaller marginal atolls; especially does this seem to have been the case with the large Southern Maldives.

The outer slopes vary greatly in different reefs, and in different parts of the same reef. When there is deep water beyond, the reef very often extends out with a gentle slope to a depth of 25 to 40 fathoms, and is studded with living coral, the bosses and knobs becoming larger in the deeper water farthest from the reef, where there are great overhanging cliffs, which eventually fall away by their own weight, and form a talus on which the reef may proceed further outward. Occasionally there is a very steep descent almost at once from the outer edge. Thus, the deeper the water beyond, the more slowly will the reef extend seaward. In reefs with a very gentle slope outside, the corals are frequently overhanging at depths of 6 or 7 fathoms, for in these instances the lower part of the sea face of the reef is rendered unsuitable for vigorous growth, in consequence of the sand which is carried in by waves coming over the comparatively shallow depths outside. In these cases, lines of growing corals, or a submerged barrier, are sometimes met with in deep water some distance seaward from the edge of the reef.

As has been stated, the lagoon in many of the smallest atolls has been filled up, but this never appears to happen in atolls with a diameter of over two miles, unless there be distinct evidence of upheaval. In perfectly formed atolls—that is, those in which the reefs are nearly continuous throughout—the deepest water is found toward the center of the lagoon, and there is a relation between this depth and the depth of water beyond the outside reefs. In North and South Minerva reefs, in the South Pacific, where the outside depths are very great, there are depths down to 17 fathoms in the lagoons, which are apparently clear of coral heads. Here we may suppose that the central parts of the lagoon have for a long time been exposed to the solvent action of sea water, owing to the slow lateral growth of the reef as a whole. In the same regions the Elizabeth and Middleton reefs, which are about the same size, have only 4 or 5 fathoms within the lagoons, and the depths outside the reefs are, at the distance of a mile, mostly within the 100 fathom line, and sometimes less than 50 fathoms.

There are also many coral heads within the lagoons. Here we may suppose the atolls to be more recent, and to have extended more rapidly than in the case of the Minerva reefs. If the depths beyond the reefs be taken into consideration, then there is usually a direct relation between the depth of the lagoon and its diameter. The greatest depths, even in the largest atolls, do not exceed 50, or at most 60, fathoms; they are usually much less. In atolls which are deeply submerged, or have not yet reached the surface, which have wide and deep openings into lagoon-like spaces, this relation may not exist. In these instances the secretion and deposition of carbonate of lime may be in excess of solution in all parts of the lagoon. It is only when the atoll reaches the surface, becomes more perfect, and its lagoon waters consequently less favorable to growth, that the solution of the dead corals and calcareous debris exceeds any secretion and deposition that may take place throughout the whole extent of the lagoon; it is then widened and deepened, and formed into a more or less perfect cup-like depression, unless the lagoon be of small size and is filled up.

The whole of a coral reef is permeated with sea water like a sponge; as this water is but slowly changed in the interior parts, it becomes saturated, and a deposition of crystalline carbonate of lime frequently takes place in the interstices of the corals and coral debris. In consequence of the solution of coral debris and the redeposited lime occupying less space, large cavities are formed, and this process often results in local depressions in some islands, as, for instance, in Bermuda. At many points on a reef where evaporation takes place there is a deposition of amorphous carbonate of lime, cementing the whole reef materials into a compact conglomerate-like rock.

The fragments of the various organisms broken off from the outer edge during gales or storms are piled up on the upper surface of the reef, and eventually ground into sand, the result being the formation of a sandy cay or shoal at some distance back from the outer edge of the reef—the first stage in the formation of dry land.

The fragments of pumice thrown up into the ocean during far distant submarine eruptions, or washed down from volcanic lands, are at all times to be found floating about on the surface of the sea, and these, being cast up on the newly formed islet, produce, by their disintegration, the clayey materials for the formation of a soil—the red earth of coral islands. Just within the shore platform these pumice fragments are found in a fresh condition, but as the lagoon is approached they disappear, the soil becomes deeper, and

the most luxuriant vegetation and largest trees are found close to the edge of the inner waters. The land is seldom continuous around the atoll; it occurs usually in patches. The water passes over the shallow spaces between the islets and through the deeper lagoon entrances, these last being kept open by the strong sand-bearing currents which pass at each tide.

The few species of plants and animals which inhabit these coral islands have been drifted to the new island like the pumice, or carried, many of them may be, by birds; lastly, savage and civilized man finds there a home.

There is no essential difference between the reefs forming fringing and barrier reefs and those which are known as atolls. In the former case, the corals have commenced to grow close to the shore, and as they grow outward, a small boat passage, and then a ship channel, is carved out between the reef and the shore by tidal scour and the solvent action of the water on the dead parts of the reef: thus the fringing reef may be converted into a barrier reef; or the barrier may be formed directly by the upward growth of the corals at some distance from the shore. In some instances the corals find a suitable foundation on the banks that surround islands and front continental lands, it may be, at a great distance from the coast, and when they reach the surface they form a distant barrier, which proceeds seaward, ultimately on a talus made up of materials torn from its seaward face.

If the foregoing considerations be just and tenable, then it would appear that all the characteristic features of coral reefs can be produced alike in stationary areas or in areas of slow elevation and subsidence, by processes continually at work in the ocean at the present time. Slow elevation or subsidence would only modify in a minor way a typical coral atoll or barrier reef, but subsidence in past times cannot be regarded as the cause of the leading characteristics of coral reefs. There are abundant evidences of elevation in coral reef regions in recent times, but no direct evidence of subsidence. If it has been shown that atoll and barrier reefs can be formed without subsidence, then it is most unlikely that their presence in any way indicates regions of the earth's surface where there have been wide, general, and slow depressions.

According to Mr. Darwin's theory, which has been almost universally accepted during the past half century, the corals commence to grow close to the shore of an island or continent: as the land slowly sinks, the corals meanwhile grow upward to the surface of the sea, and a water space—the lagoon channel—is formed between the shore of the island and the encircling reef, the fringing being thus converted into a barrier reef. Eventually, the central island sinks altogether from sight, and the barrier reef is converted into an atoll, the lagoon marking the place where the volcanic or other land once existed. Encircling reefs and atolls are represented as becoming smaller and smaller as the sinking goes on, and the final stage of the atoll is a small coral islet, less than two miles in diameter, with the lagoon filled up and covered with deposits of sea salts and guano.

It is at once evident that the views now advocated are in almost all respects the reverse of those demanded by Mr. Darwin's theory.

The recent deep sea investigations do not appear in any way to support the view that large or small islands once filled the spaces now occupied by the lagoon waters, and that the reefs show approximately the position of the shores of a subsided island. The structure of the upraised coral islands, so far as yet examined, appears to lend no support to the Darwinian theory of formation. When we remember that the great growing surface of existing reefs is the seaward face from the sea surface down to 20 or 40 fathoms, that large quantities of coral debris must be annually removed from lagoons in suspension and solution, that reefs expand laterally and remain always but a few hundred yards in width, that the lagoons of finished atolls are deepest in the center, and are relatively shallow compared with the depth of the outer reefs, then it seems impossible, with our present knowledge, to admit that atolls or barrier reefs have ever been developed after the manner indicated by Mr. Darwin's simple and beautiful theory of coral reefs.

THE COLLECTION AND PRESERVATION OF PLANTS.

EVERY one who is interested in natural history knows how useful it is to make collections. As the time during which a plant can be studied in a fresh state is very limited, the necessity of possessing, for such study, working tools and numerous works of difficult carriage makes the herbarium absolutely indispensable to the botanist. With certain care, however, it is possible to succeed in making collections of dried plants which closely resemble these same plants in a fresh state, and which at the same time permit of working at leisure and facilitate comparisons with duly labeled specimens that have undergone the same preparation. On an excursion, the botanist therefore has only to occupy himself with the collection of materials for study which he will utilize upon his return.

Of course, plants in a dried state no longer possess their natural aspect, but with a little experience, a person can easily restore this in his mind, and if, at the moment of collecting, he takes care to note certain characteristics that are necessarily modified through desiccation, it then becomes very easy to re-establish things.

It is of great advantage to the botanist to be able to preserve the plants that he has gathered and named, and this extraordinarily facilitates future work. If he makes a publication, he will be able to show the specimens that are the subject of it, and these types will always permit of rectifications by competent persons. It is due to the herbaria formed by travelers that we are gradually coming to be acquainted with the vegetation of the various parts of the world. Our large national museums receive these and hold them at the disposal of botanists, who describe their contents, and who can then draw up floras.

It thus becomes easy to seek, among the vegetable productions of each country, those that we may have an interest in studying. In this respect, horticulture and agriculture are absolutely tributaries of botany; so we should not like to see travelers omit from their labels any details as to the uses of useful plants and as

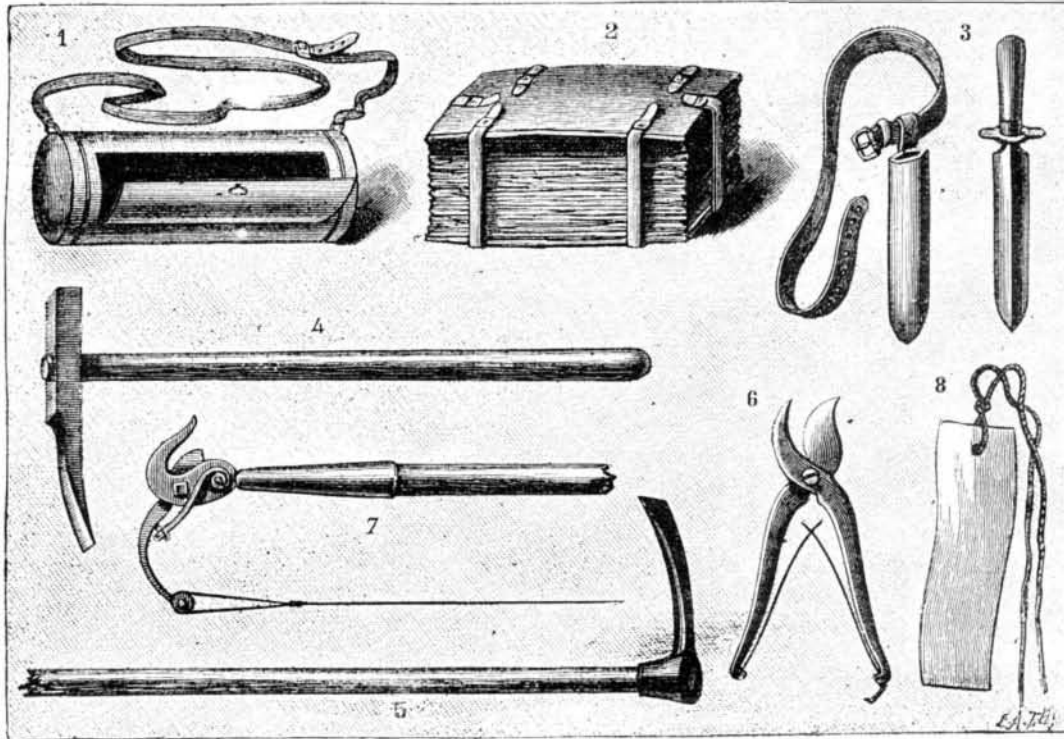
to the processes of culture to which they are submitted. The herbarium is not only useful, but it is a pleasure to consult it. With every specimen there are connected remembrances which years cannot obliterate, and which give it a value so much the greater in proportion as there has been more difficulty in obtaining it.

Says Jean Jacques Rousseau: "All my botanical excursions, the various impressions of the place, the objects that have struck me, the ideas that have occurred to me, the incidents that have mingled therewith, all this has left me impressions which are renewed by the aspect of the plants collected in these same places."

"I shall never more see those beautiful landscapes, those lakes, those groves, those rocks, those mountains, whose aspect has always touched my heart; but

ing the dried specimens upon. This is a guide in the collection of specimens, which it is then easy to gather of the proper dimensions. When these are too long to go into the box, they are bent at a sharp angle as many times as may be necessary, the stem being crushed at the spot where the bend is to be made.

If large collections are to be made, the vasculum will have to be of larger size. The usual dimensions are 20 inches in length by six in diameter. There are boxes with one or more compartments, but we like the other kind better, as we prefer to have a pocket box in which to put the small plants and delicate things that have to be carefully preserved. The aperture in the box should be large enough to allow the plants to be put in and taken out easily.



FIGS. 1 TO 8.

1. Botanical Box. 2. Portable Press. 3. Bark Knife. 4. Cosson Pick. 5. Decaisne Pick. 6. Shears. 7. Apparatus for Gathering Branches. 8. Tag.

now that I can no longer travel to these pleasing countries, I have merely to open my herbarium, and I am soon transported thither. The fragments of plants that I gathered there suffice to recall the beautiful spectacle to me. This herbarium to me is a journal of herborizations which causes me to begin the latter again with a new charm and produces the effect of a vision that paints them over again to my eyes."

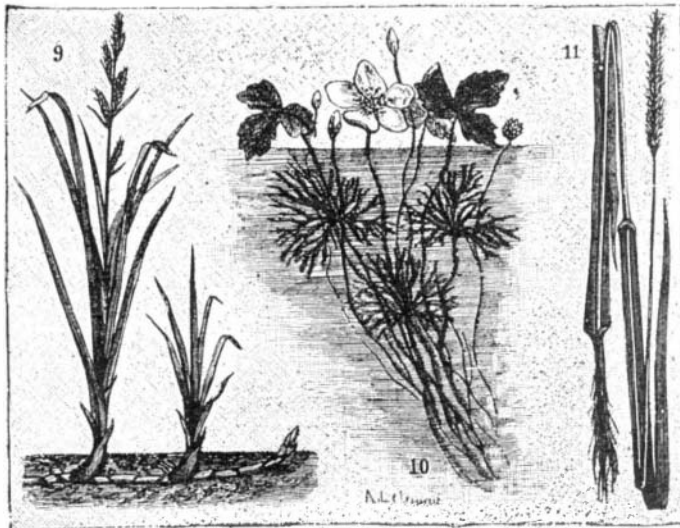
Herborizations.—In order to learn how to collect plants, one will do well to accompany some of the public excursions that are made every summer under the direction of several botanists. After a few excursions a person will be able to continue them well enough alone. In order to be a botanist, it does not alone suffice to familiarize one's self with the rare plants of the region where he dwells, and it is an error to think that public herborizations are made for the sole purpose of making localities known. As regards the study, commonest species have as much importance as others, and it is with these that it is necessary to begin. Therefore it is not necessary to make very lengthy excursions to begin with, and it is by degrees that one should extend the circle of his investigations with the object of finding things that he has not yet studied. It is preferable to collect but a few species at a time, so that they can be the more carefully examined on one's return home, and be properly prepared for the herbarium.

When a person is traveling, the conditions are changed. As one cannot carry his books with him, the wisest thing to do is to collect the largest number of

Instead of a botanical box, some persons use a temporary press (Fig. 2) to put their gatherings in. This consists of two pieces of strong cardboard or leather, between which are placed sheets of paper that serve to isolate the specimens. The whole is held in place by means of leather straps. This press permits of the easy preservation of species with caducous flowers, such as the anemones, flaxes, certain ranunculaceae, etc. The beginning of the preparation that they undergo permits of having them in a perfect state, while they would have lost a portion of their organs had they been simply put into a botanical box. Unfortunately the press is unwieldy and difficult to carry. Another drawback resides in the use of the numerous straps necessary to hold it together, and which involves a considerable loss of time at each collection.

The Tools of Extirpation are numerous and varied, each having its merits and defects. For herborizing in sandy places a simple bark knife suffices. It has the advantage of being light and of being easily carried in a sheath that has been devised for it. This apparatus may be replaced by the poignard knife (Fig. 3).

For hard earth, and for plants whose roots penetrate the earth deeply, these tools are absolutely inadequate, and they should be replaced by the Cosson pick (Fig. 4), which is the apparatus generally adopted. It has the advantage of being very strong and also of being capable of entering the cavities of rocks, owing to the shortness of its handle. But the slight length of the handle renders it difficult to carry this tool, which



FIGS. 9 TO 11.

9. Plants of small size. 10. Aquatic Crowfoots. 11. Plant bent.

specimens possible, to prepare them well, and to take notes that may be utilized whenever it is possible to do so.

The Botanical Box or Vasculum (Fig. 1) is a cylindrical tin box with elliptic ends, and usually painted green. It is provided with a leather strap that permits of its being slung over the back, so as to leave the arms free. It should, as far as possible, be made of the length of the paper that has been adopted for mount-

weighs heavily in the hand. The Decaisne pick (Fig. 5), which certainly is not as strong, is, in this respect, much more convenient, for it may be used as a cane. It can be used also for pulling the branches of trees downward and for pulling in such aquatic plants as grow up a small distance from the edge of the water, etc.

Fig. 6 shows a good pair of shears for collecting branches of trees or shrubs, and spiny plants and