THE GROWTH OF CORAL REEFS.

A LECTURE BY PROFESSOR AGASSIZ.

[Reported for the Scientific American.]

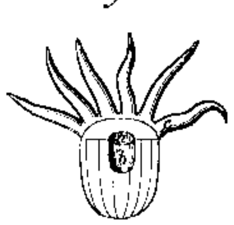
On Sunday evening, Feb. 2, Prof. Agassiz delivered the third lecture of his course on the goodness and wisdom of God, as manifested in his works. In this course he draws his illustrations from the science of zoology. In his first lecture he explained that the animals of the globe are divided into four orders, the simplest and lowest of which is the order of the Radiata. In these animals the parts radiate from a central vertical axis, like the spokes of a wheel which lies in a horizontal position. Of the three principal classes of radiates the lowest is the class of polyps, and the most interesting sample of these is that wonderful animal that builds the coral reefs. On being introduced the lecturer said :—

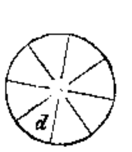
Accustomed to the narrow walls of a lecture room, I have never addressed an audience like this; and if I should not succeed in expanding my voice so as to be heard in the remotest parts of the building, I desire to apologize in advance.

A question which excited the greatest interest a few years since, was in relation to the time at which animals first made their appearance on this earth. It was formerly supposed that we knew exactly how many years had elapsed since all animals were created, but on examination it is found that the chronology of Genesis relates only to man, and we now know that the lower orders of animals existed long before man was created. I will give you an account this evening of the animals that build the coral reefs, and will present some facts indicating the periods during which they have been at work.

Coral is not the shell of an animal, but it forms the hard part of his body, just as much as our bones are parts of our bodies. If any of you have seen the jelly-like animal that floats about the docks of our harbors—the Sea Anemone—you can form a very good idea of the animal which I am going to describe.

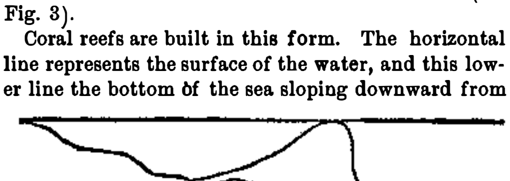
Fig. 1. Fig. 2 Fig. 3.





I will draw a rough representation of the coral animal upon the blackboard (see Fig. 1). These (*c*) are the tentacula, this (*a*) is the mouth, this (*b*) is the digestive cavity. These thin divisions (*d*) radiate from the center as shown in this cross section (Fig. 2); this structure placing the animal in the order of the Radiata, the lowest of the four orders; and it belongs to the lowest class in this order—the polyps. These tentacula are furnished with numerous minute hairs or cilia, which by their motion create a current of water into the mouth of the polyp, and thus draw in its food. The carbonate of lime which forms the durable part of the animal—the part with which we are all familiar—is drawn in by the animal with its food, and is secreted by its organs and deposited on the outer wall of its body and on these radiating divisions; thickening them in this manner (see Fig. 3). The soft parts of the polyp are capable of such variations in volume that they may be expanded to this extent (see Fig. 1) or contracted so as to be contained in this cavity in the upper portion of the cylinder (see Fig. 3).

Coral reefs are built in this form. The horizontal line represents the surface of the water, and this lower line the bottom of the sea sloping downward from



the shore. The reef you see is nearly vertical on the sea side, and considerably inclined on the side next the land. They are always commenced in water from 10 to 12 fathoms in depth, never more than 72 feet, never less than 60.

This statement may seem to conflict with that of Capt. Cook, that he brought up corals in the Pacific Ocean from a depth of 2,000 feet. But, though I have no doubt of the truth of Capt. Cook's statement, and though I know that mine is correct, there is no conflict between them. It is ascertained that the bottom of the Pacific Ocean is subsiding, and we know the direction of the subsidence. The corals that Capt. Cook recovered from so great a depth were the limestone remains of animals that had long been dead. They grew at the usual proximity to the surface, and were carried down with the settling of the ocean bed.

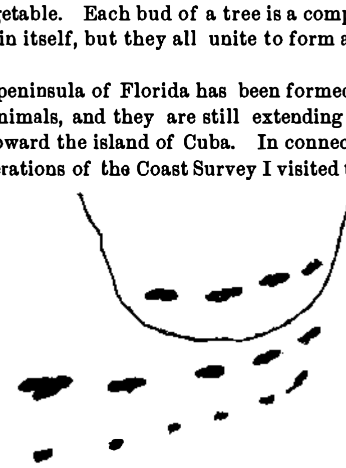
There are several species of corals, and each lives at a certain depth beneath the surface; being unable to exist either above or below the zone for which it is adapted. This is not strange when we consider the very soft character of its body, and the rapidity with which the pressure of water increases with the depth. At the surface there is a pressure of one atmosphere, at a depth of 32 feet a pressure of two atmospheres, and at a depth of 64 feet a pressure of three atmospheres, and this is as great a pressure as any of these animals can bear.

Each coral reef is built by four species of polyps; the bottom being constructed by the species which lives at the greatest depth, and the several parts above by species inhabiting corresponding strata of water. The reef builder lays the foundation at the base of the outer wall; and the growth is more rapid there than it is in the parts nearer the land. For this polyp is adapted to clean sea water, and will not live in the foul water inside the reef. The reef, therefore, soon assumes a form similar to that which it has in its finished state—the form indicated in the drawing. When the species of polyp that lives in water of 10 or 12 fathoms in depth has carried the structure up through the zone which it inhabits, his labors cease, and the work is continued by a second species. As this species does not require water so pure as the first he extends his growth toward the shore, thus sloping the reef as represented. Having grown upward through his stratum of water, his growth ceases, and a third and fourth species complete the reef.

It was at one time a mystery to us that one species could thus apparently grow out of another. But, in examining the mode of reproduction of these polyps, I discovered facts which explained the mystery. Though the mature animal is attached immovably to the rock, when first hatched he swims through the water, and is confined to the same stratum of depth as in the matured state. When swimming about in this undeveloped state, if he encounters the upper surface of a coral reef which has grown up to his stratum of water, he attaches himself to it and then begins to grow; thus continuing the structure.

These polyps multiply and grow by a process of budding. A protuberance appears upon one side of the body, which finally develops into a perfect animal; but is not separated from the parent, making a compound animal of numerous individuals united together. However strange this process may seem to us in the animal kingdom we are familiar with it in the vegetable. Each bud of a tree is a complete individual in itself, but they all unite to form a common plant.

The peninsula of Florida has been formed by these little animals, and they are still extending it southward toward the island of Cuba. In connection with the operations of the Coast Survey I visited the south-



ern part of Florida to examine the coral reefs, and I made some efforts to ascertain the rate of their growth. The foundations of Fort Jefferson, on Tortugas Island, and of Fort Taylor, at Key West, showed that the reefs had risen one inch in fourteen years. This would give in round numbers, after allowing for inaccuracies, say one foot in a century. This is doubtless more rapid than the actual growth, as the mass near the bottom is crushed together and compressed by the superincumbent weight, and it would probably take at least two centuries to grow one foot. But calling it one foot in a century it would take a reef sixty centuries, or six thousand years, to rise from a depth of sixty feet to the surface.

Let this indicate the outline of the southern end of Florida. Nearly parallel with the coast, diverging from it toward the west, is a row of small islands, called keys, and beyond these again a row of still smaller islands, which are called coral reefs. On examining the keys, too, they are found to be reefs of coral. Now, as the reef-building polyps can live only in the clean sea water, and perish if brought into the muddy water inside the reefs, we come to the conclusion that the keys were built up before the outer reefs were commenced. And if we allow the same rate of growth for them, their foundations must have been laid at least 12,000 years ago.

Along the coast is a marshy tract of land called the Indian Hunting Grounds, and beyond this, still parallel with the coast, is a row of low elevations called hammocks, rising some ten or twelve feet above the surface of the swamp, the mountains of that district; and these, on examination, are found to be still older coral reefs, carrying back our chronology another 6,000 years. Beyond these there is still another row, making 24,000 years.

The distance from the outer reefs to those last named is fifteen miles. I am told by intelligent officers of the army who have explored the country to Lake Okeechobee, sixty miles inland, that it is all formed of series of coral reefs. In fact, the whole peninsula of Florida is a coral formation, and we are brought to the conclusion that hundreds of thousands of years have been consumed in its slow growth.

And yet this is to-day in the chronology of our globe. The polyps that have built up Florida belong to living species. In the divisions of geologists this is the present formation. When we examine rocks formed by extinct species, we are led to a knowledge of periods still more inconceivable, during which nature has been conducting her operations.

DISCUSSION ON GUNPOWDER.

At the regular weekly meeting of the Polytechnic Association of the American Institute on Thursday evening, January 30th, the discussion was resumed on the subject of the application of chemistry to the military art—this subject having been continued from the meeting of the previous week.

Prof. JOY—Three years ago Mr. Bunsen, Professor of Chemistry in the University of Heidelberg, examined with great care the products of the combustion of gunpowder, and as the results were quite different from the statements of our text books, an account of them may interest this meeting. Bunsen found that of the substances formed by the combustion of powder, 67.7 per cent are solid, and 31.24 per cent are gaseous. The following is his list of both classes :—

PRODUCTS OF THE COMBUSTION OF 100 LBS. OF POWDER.

Solids.		
Sulphate of potassa	42.20	
Carbonate of potassa	12.60	
Hyposulphite of potassa	3.20	
Sulphide of potassium	2.10	
Sulphocyanide of potassium	.30	
Nitrate of potassa	3.70	
Charcoal	.70	
Sulphur	.10	
Carbonate of ammonia	2.80	
		67.70
Gases		
Nitrogen	9.90	
Carbonic acid	20.10	
Carbonic oxide	.90	
Hydrogen	.02	
Sulphide of hydrogen	.18	
Oxygen	.14	
		31.24
Total		98.94

As so large a portion of the powder is formed by combustion into substances which are solid, the gun would soon be completely filled up and rendered useless, were it not that most of the solids are thrown out by the expansion of the gases. Bunsen states the pressure at 4,374 atmospheres, 1,000 of which are due to the expansion by heat.

Bunsen's analyses of the powder which he used showed it to be composed of the following substances:

Nitrate of Potassa	79.99
Sulphur	9.84
Carbon	6.69
Hydrogen	.41
Oxygen	3.07
Total	100.00

Prof. SEELY—I would ask Prof. Joy if the account gives the mode in which the powder was burned?

Prof. Joy—It was shaken from the end of a whip stock into a retort in such a manner that one grain was burned at a time. The gases were drawn by an aspirator into tubes from which the air had been expelled, and the tubes were sealed until the gases could be examined.

Prof. Seely—Bunsen's analyses are exceedingly interesting and instructive, but they do not prove that our old notions of the combustion of gunpowder, when burnt in the usual way in a cannon, are erroneous. The mode in which he burnt his powder would necessarily give different products. As there was no pressure in his retort, the temperature was very much lower than that at which powder is burnt in a gun. It is a well known law that the products of decomposition by heat vary with the temperature, and the higher the temperature the simpler the compounds. If the quarternary compounds of Bunsen's list were produced at the low temperature of his retort, we should naturally expect at the higher temperature of the gun the binary compounds usually described. That there is bisulphide of potassium left in the gun we know by the smell and taste. We should certainly not find at this degree of heat so unstable a compound as the carbonate of ammonia.

Mr. Rowell—It is necessary to understand the office of the several ingredients of powder before we can obtain substitutes for either. The use of the sulphur is to kindle the mass. It burns at a low temperature and gives out little heat in burning, but sufficient to ignite the charcoal. Then the heat from the charcoal completes the combustion and expands the gases. In this friction match you know there is on the outside a little phosphorus, beneath that a little sulphur, and beneath the sulphur the stick of pine wood. The phosphorus in burning generates but little heat, the sulphur some more, and the wood more still. In this cup I have a little alcohol of 95 per cent. If I light the match and dip it immmediatly into the alcohol while the phosphorus only is burning, you see that the alcohol is not ignited, but the match is extinguished. But if I wait till the sulphur gets to burning then you see the alcohol is set on fire. The wood in burning generates more heat than the sulphur, and I have found that in lighting an oil lamp it is necessary to wait till the wood portion of the match begins to burn, the sulphur flame not being sufficiently hot for this purpose.

Prof. Seely—Mr. Rowell's experiment is a very beautiful one, and demonstrates in the most satisfactory manner the fact that the flame of phosphorus is less intense than that of sulphur. At first sight this fact might seem to form an exception to the general law that the heat generated by the burning of any substance is in proportion to the oxygen which it consumes ; for, a given weight of phosphorus in burning combines with one-eighth more oxygen than the same weight of sulphur. The equivalent of phosphorus is 32, and in buring it forms phosphoric acid, PO_5. The equivalent of sulphur is 16 and in burning it forms sulphurous acid, SO_2. So that while 32 parts by weight of phosphorus combine with 40 parts of oxygen, 16 parts of sulphur combine with only 16 parts of oxygen. The explanation is to be found in the fact that the phosphorus flame is diffused through a larger space than the flame of sulphur ; and, consequently, though the quantity of heat is greater, it is less intense. The power of heat to set any substance on fire depends upon its intensity.

Sea Birds.—The question is often asked where do sea birds obtain fresh water to slake their thirst? But we have never seen it satisfactorily answered till a few days ago. An old skipper, with whom we were conversing on the subject, said that he had frequently seen these birds at sea, far from any land that could furnish them with water, hovering round and under a storm cloud, clattering like ducks on a hot day at a pond, and drinking in the drops of rain as they fell. They will smell a rain squall at one hundred miles, or even further off, and scud for it with almost inconceivable swiftness. How long sea birds can exist without water is only a matter of conjecture ; but probably their powers of enduring thirst are increased by habit, and possibly they can go without for many days, if not for several weeks.—*Wilson.*

Masses of platinum, weighing 53 ounces, are frequently smelted in 13 minutes by the oxhydrogen blow pipe, by Dr. Roberts, Dentist, New York.

Correspondence.

Trial of Warlike Inventions.

Messrs. Editors :—It must be truly gratifying to many of the inventors of warlike weapons to have noticed in the Scientific American of the 25th inst. your opportune and pertinent remarks and suggestions under the above caption. Now that the Cabinet makers at Washington are being stirred up by the stern realities of war, and are busy in the manufacture of bureaus in the several departments, it is to be hoped that you will continue, through the Scientific American, to advocate and press the measure suggested, until Congress shall be induced to take up the subject and appoint the commission referred to. It is suggested, as an auxiliary in the furtherance of this object, whether the inventors themselves should not unite in concert of action, by petition or otherwise, to bring the subject tangibly before Congress. As pertinent to this question I have observed recently in some of the public papers the representation made by Charles Ellet, Jr., Civil Engineer, of the various and repeated attempts made by him to enlist the attention of the government in reference to his proposed plans and propositions for the construction of steam battering rams. While he has been knocking for admission at the several doors of the War and other departments, until his knuckles have become callous, and has abandoned the effort in despair, we find similar plans and purposes have been adopted in several European governments, and carried out for practical demonstration. The English government is rapidly augmenting its navy with iron-clad steam battering rams, and it is possible, unless the appearance of things now visible in the political horizon should change considerably, that some of these improved war vessels may be used to perform a new feat in naval tactics, viz., to charge bayonet, on some of our own (in this particular) defenceless navy. Is it not a little curious, to say nothing worse about it, that many very important and useful American inventions must become exotics before they can be relished and appreciated at home? Like the solanum of the aborigines of this country, their merits are not discovered until planted and raised in a foreign soil. Stevens's iron-clad battery, I believe, was originally devised and commenced several years before the English iron clad *Warrior* or the French *La Gloire* was thought of. The secretive and go-it-blind policy, however, adopted by the government in reference to the mode of constructing this vessel, has tended to place the navies of several foreign governments, in this particular, considerably in advance of our own. Had a commission, as proposed in the article above-referred to, existed years ago, whose duty it would have been to examine and test the plans and suggestions for the construction of this vessel in its incipiency, can we reasonably doubt that the final result would have been a vast saving to the government and an honor to the country? In many of the European governments large premiums are frequently offered to stimulate the inventive genius of the whole country. The difficulties encountered by Mr. Ellet, as above mentioned, is doubtless the experience of most of the inventors of warlike inventions in these troublous times of civil war and rebellion. All the departments at Washington, and especially the Ordnance and War Departments, are overwhelmed with business in the usual routine of their offices, and have no time to spare to investigate new plans or projects, however important and useful the same may be to the government in the prosecution of the present war. This state of affairs, we think, is a solid argument in favor of the propriety and necessity of the appointment of a commission, as suggested.

The improvement in projectiles, as described in the Scientific American, Nos. 25 and 26, Vol. V., I have thought contained the germ of novelty that might probably lead to some useful results in the science of gunnery. To project shot or shell to the greatest possible distance, or, in other words, to have guns, the range whereof should far exceed those of the enemy we supposed to be a great desideratum. Desirous that the United States Government might have the advantage of this improvement, should it, on a practical examination, be found valuable, the plan and description thereof have been communicated to several of the departments at Washington, but, I presume, as Mr. Ellet and a hundred others are before me, and as these departments may have adopted the barber shop rule—first come first served—I shall have to wait a little longer before I shall have the pleasure of hearing from them. The difficulty in testing my proposed improvements myself is the want of a suitable place where ample range for the purpose can conveniently be obtained. Around Trenton we have no place where a range of several miles could be obtained without great risk to life and property. Charles Potts,
Civil Engineer.

Trenton, N. J., Jan. 31, 1862.

The Expansion Question.

Messrs. Editors :—I was much pleased to receive Mr. M'Elroy's reply, on page No. 5, this volume, Scientific American, to this question, but, although admitting the correctness of his figures in general I cannot bring myself to the belief that there would be a saving of 48 per cent by using the larger cylinder, as he has attempted to show. There is one point which Mr. M'Elroy seems to have entirely overlooked, viz., the difference in the displacement of the cylinders. The difference in the area of a 14-inch and a 22½-inch cylinder is 244. This multiplied by 300 feet will give 50.8 cubic feet of steam of 15 pounds pressure, or 152 cubic feet of steam of 50 pounds pressure per minute required by the larger cylinder over and above that required by the smaller one for displacement. This 152 cubic feet of steam added to the 165.79 cubic feet required by Mr. M'Elroy's figures, gives 317.79 cubic feet against 322.25 required by the smaller cylinder, showing a saving in favor of the larger cylinder of 1½ per cent only, and then not charging the larger cylinder with the increased cooling surface, friction of piston and its liability to a larger amount of leakage than the piston of the smaller cylinder.

If I have committed any error in this I should be glad to have it corrected, but, as it is, I think the question still remains open. John West.

Norristown, Pa.

Sorghum in Ohio.

On the 7th ult. a sorghum convention was held at Columbus, Ohio. Fifteen splendid samples of sugar were presented, beside enough molasses to load a dray. The sugar was of very fine color and handsomely crystallized. From the discussions, it would seem that large numbers of cane growers had succeeded well in making sugar upon the Cook Evaporator, and, it is said, all the samples in the Convention were made on this evaporator. About 3,000,000 gallons of sirup were made in this State last fall, which has been sold at an average of 60 cents per gallon, or about $1,800,000! Many of those who tried succeeded in crystallizing their sirups in about 24 to 48 hours. One gentleman, Mr. Myers, of Springfield, said he had made 160 barrels, another 50, and so on. Mr. Myers also presented a specimen of wine equal to Madeira. A Committee was appointed to compile the most valuable information obtained for publication.

Silver Smelting in San Francisco.

Several American capitalists have invested largely in Mexican silver mines, and large quantities of silver ores have been imported into San Francisco where they can be smelted at less cost than in Mexico. Heretofore these ores have been admitted duty free, but lately the custom-house officers have adopted a new rule, and levied a duty of ten per cent upon them. This has drawn out a remonstrance from those who are engaged in smelting the ores. They state that while bar silver is admitted duty free, it is very unwise to levy ten per cent on the ore, as it gives employment to capital and a large number of persons in San Francisco ; whereas, if they were smelted in Mexico their product would be admitted free. The amount of silver smelted from Mexican ores in San Francisco is about 16,000 ounces per month.

The Japanese government has officially signified its intention to forward articles to the great exhibition which is to be held at London next summer. The Ministers of Foreign Affairs, Koodze Gamatonskami and Ando Tsoo Tsoosima Nokami, have written to the English Consul that "it would be a matter of great joy to cause the glory of Japan to sparkle in a foreign country."