CHEST DEVELOPMENT IN YOUNG PERSONS.

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IN the perfection of modern educational methods, the physical needs of the individual have been almost entirely ignored. Facilities for the acquirement of strength and endurance have been, to a great degree, wanting. Teachers have, as a rule, possessed no knowledge of the laws of physical growth and development, and consequently the student who desired to perfect himself physically was obliged either to exercise according to his best judgment, which is bad, or to put himself under the care of incompetent instructors, which is even worse. The past few years have, it is true, given us gymnasia and various apparatus for physical development, but have they been properly used? Evidently not. In the report of the commissioner of education for 1889, that official regrets his inability to report a general adoption of physical training in the public schools, and says that "though thousands of dollars have been invested in apparatus to be used in the development of the mind, no provision worthy of serious consideration has as yet been made for strengthening the body, upon whose sound condition effective mental effort greatly depends."

It is not my intention to advance in the present paper the claims of physical education, or to illustrate the definite and remarkable results of judicious and persistent exercise. I prefer rather to bring to the attention of parents, teachers and others but one phase of the question, which seems to me to outrank all others in its importance to the present as well as to future generations. The child who first enters the school room is deficient physically as well as mentally. The body is undeveloped and often unsymmetrical. There is most likely imperfect lung expansion from the very first, and, in default of any rational treatment for it, the condition becomes more and more exaggerated, until finally it is past all hope of remedy. The student may have attained a high degree of scholarship, but he has acquired at the same time a physical conformation unfit for endurance and incapable of resisting disease. Consumption destroys fully one-seventh of our population, and it is during school life that the foundations of the disease are too often laid. It is preeminently a disease of imperfect nutrition. It attacks the crippled and poorly developed lung just as certainly as it shuns the one which is fully expanded and in constant and active service. Numerous observations have established the existence of a constant ratio between consumption and deficient lung expansion. In those cases where the degree of development fell below a certain figure, chronic disease was extremely prevalent, while in the others it was of extremely rare occurrence. In view of these and other facts, it is extremely doubtful whether consumption can coexist with complete lung expansion.

The effects of this form of physical culture have been so well summarized by a recent writer that a few extracts from his article are here quoted. He states: "While it is true that many undeveloped persons enjoy fair organic health, greater respiratory and muscular power would unquestionably make such lives more effective and longer. A roomy thorax and strong heart are no mean allies in resisting the assaults of disease. A few extra cubic inches of respiratory capacity, or a small reserve of disciplined cardiac power, may suffice to determine a favorable issue in pneumonia, pleurisy or typhoid. Every inch which a man adds to his chest measure adds to the measure of his days. Physical development can, perhaps, be excessive, yet resulting injury is limited and personal, whereas neglect of bodily improvement sins against posterity." There is a great lack of information among people generally, regarding the beneficial results of such training and the amount of development which may be attained. For the information of such it may be stated that nowhere are these effects more definite and invariable. They are as capable of demonstrating as any mathematical problem and no one need fail to secure results proportionate to the amount of labor expended. Abundant confirmatory evidence may be found in almost any work on this subject.

By one hour's daily exercise for eight months, twelve men from nineteen to twenty-eight years of age were found by Maclaren to have gained an average of two and seven-eighths inches in chest expansion, while the greatest gain in a single individual was five inches. In four and a half months, twenty-one students of Woolwich Academy, averaging eighteen years of age, gained on an average two and five-tenths inches in chest measurement, while the largest gain was five and a quarter inches. At the end of one year's steady practice, two persons, aged sixteen and twenty years, were found to have gained in chest growth five and six inches respectively. The reports from Amherst College, as reported by Dr. Hitchcock, show that the students, at the end of their four years' course, by a half hour's light exercise four times a week, gained one and twenty-one hundredths inches in chest expansion, while those of Bowdoin College, by the same expenditure of time in heavier exercises, gained in six months one and seventy-five hundredths inches. These figures not only serve to illustrate the constant and progressive growth that occurs, but they also indicate that decided improvement may be counted upon even in those who have attained or passed the age of maturity.

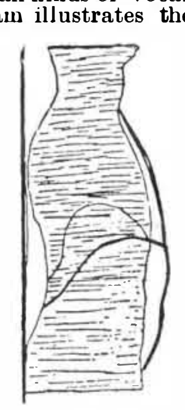
In order to more fully appreciate and utilize the various methods for promoting chest development, it is necessary to consider briefly some points in the anatomy and physiology of the lungs. These may be described as collections of air cells, inclosed within elastic walls composed of bones and muscles and bounded below by a strong muscular partition which forms the floor of the cavity and which is known as the diaphragm. Their function is respiration, a process by which oxygen is introduced into the body and effete material removed from the same. The respiratory act is composed of two movements, inspiration and expiration. During the first, the chest is enlarged in all its diameters—vertically, by the contraction and descent of the diaphragm, and transversely and laterally, by the rotation of the ribs upon their axes and the action of the various muscles attached to the chest walls. During the expiration the reverse occurs. The diameters of the cavities are shortened by the ascent of the diaphragm, the depression of the ribs, and the recoil of the elastic tissue of the lungs. When it is performed forcibly, several of the chest and abdominal muscles share in the act. Inspiration is an active process, and most of the force exerted is for the purpose of overcoming the resistance offered by the elastic tissues of the lungs and of the cavity containing them. Hence the necessity for muscular development in these parts. In the physiology of respiration we find many important and suggestive facts which have a direct bearing on the subject in hand.

The capacity of the lungs is about two hundred and thirty cubic inches. Of this amount of air, about one hundred cubic inches remains constantly within them and cannot be expelled. It is renewed very slowly under the laws governing the diffusion of gases. About one hundred more cubic inches is more rapidly changed, as it can be taken in and expelled by means of forced breathing. During ordinary inspiration, however, only about twenty or twenty-five cubic inches is inhaled and only about one-tenth of the whole is renewed. It has been shown, and this can be understood from the facts above quoted, that the capacity of these organs is nearly a third greater than is really necessary to support life, the surplus being held in reserve for emergencies which may arise. Hence it follows that if two-thirds or three-fourths of the lungs perform the work of the whole, there are portions which remain inactive. And such is really the case. The apices and small sections of the circumference and bases are, in many persons and by ordinary methods of breathing, very little used, and it is a most suggestive fact that these are the very portions of the lungs which are first seized upon by consumption. Mays has recently offered valuable negative proof of the above by showing that women who lace excessively, and are thus obliged to practice clavicular breathing, are remarkably free from disease of the upper thirds of the lungs.

To fully develop the chest and put into active service each individual air cell is, therefore, the object of the gymnastic exercises here described. The proper performance of the respiratory act forms the basis of all successful methods for chest development. The most careful and persistent training will accomplish little if this essential be disregarded. We cannot hope to increase the chest capacity simply by developing the muscles upon the exterior walls. These, it is true, sustain the head and shoulders, and assist in elevating the ribs, but it is really the pressure outward, exerted by the dilating air cells, which does a greater part of the work. The muscles are merely adjuvants.

There are three ways by which air may be taken into the lungs: First, by pressing the latter outward against the walls of the chest, the method most commonly practiced; second, by drawing the lungs upward by the action of the collarbone and shoulder blades; and third, by contracting the diaphragm and abdominal muscles, and allowing the lungs to dilate from their bases upward. This latter is the only true method of breath taking, and should be thoroughly mastered before proceeding further. It is, perhaps, unnecessary to state that in this, as in all other gymnastic exercises, the clothing should be loose and free about the waist.

Begin as follows: Stand erect and with head and shoulders drawn well backward. Expel all the air from the lungs by contracting the chest and abdominal muscles. Next, holding the chest quite immovable, allow the air to enter the lungs by the action of the abdominal muscles alone. If properly performed, the first movement will be of a protrusion of the abdomen and an increase in the transverse diameter of the lower portion of the chest. Inhale, at first, only a moderate amount of air, but gradually increase the depth of the inspiration until you become proficient in the exercise. Remember that the protrusion of the abdomen and the expansion of the chest occur almost simultaneously during each inspiration. Having filled the lower portion of the lungs in the manner described, the first two methods above noted may be employed to distend the apices. By the abdominal method, the expiratory act is much better regulated, more easily controlled, and is performed with the minimum degree of muscular effort. For these reasons, it forms a prominent part in all kinds of vocal culture. The accompanying diagram illustrates the antero-posterior



enlargement of the chest produced by this method alone. The heavy lines show the contour of the chest after a full inspiration.

One of the more simple exercises is what is known as forced voluntary breathing, practiced, of course, after the method above described. Stand erect, and then take slowly a series of deep inspirations. Then take a long breath and hold it as long as possible. By a little practice this period may be easily increased from thirty seconds to a minute and a half. Repeat until the lungs feel a little tired. Again take a deep inspiration, and then count in a loud voice as long as you can. One should be able in a few days to reach as high as seventy-five. Exercises such as these will also test your proficiency in abdominal breathing.

Among the out-door resources, running and walking occupy a justly prominent place. Unlike some of the other exercises, they act upon the lungs indirectly by increasing the demand for oxygen on the part of the tissues. While at rest the amount of air used by the lungs per minute is about 430 cubic inches; while walking at the rate of four miles an hour, 2,200 cubic inches; and while walking at the rate of six miles an hour, 3,200 cubic inches. Thus, by the increased depth and rapidity of the inspirations, these is a prompt renewal of the residual air and an expansion of the less used portions. As ordinarily practiced, these exercises will sometimes fail to produce satisfactory results. Success here, as well as elsewhere, depends in great part upon attention to details. Hence the blame, if any is attributable, lies to the exercises rather than to the method.

Particular attention should be given to the position of the shoulders and chest, and the one exercising should inhale large amounts of air slowly rather than small quantities at frequent intervals.

The novice who attempts to run any considerable distance soon finds himself out of breath. The respiration becomes short and labored, the pulse rapid, and a sense of extreme exhaustion is promptly experienced. Thereupon the rate of speed naturally becomes lessened, during which time a reciprocal action becomes established between the heart and lungs. The more remote portions of the latter become distended, and thus the increased circulation of blood through the air cells can be provided for, thereby lessening the strain upon the heart and blood vessels, and permitting thorough oxidation. Now, under rational methods of training, these phenomena should never occur. The lungs should be equal to all the ordinary demands made upon them, and it is the fault of the individual if they are not. While brisk walking is allowable, fast running is not. All competitive effort, and all attempts to break a record, are disastrous as regards the objects you are striving to attain. After acquiring as great a walking speed as is consistent with a graceful and easy carriage, begin the running exercise, gradually increasing the distance, but not the rate of speed. A five-mile gait is quite sufficient, and a healthy person in good form ought to cover two or three miles easily and without experiencing at any time any marked shortness of breath or sense of exhaustion. This result can be easily secured by persistent practice and careful attention to the foregoing suggestions.

The success of any method of training depends not only upon its inherent worth, but upon the ease and readiness with which it can be put into practice. Gymnastic apparatus is not accessible to the masses, while of those having access to the ordinary gymnasium, but a very small proportion make good use of their opportunities. As regards children, there is absolutely nothing at their disposal. There is demanded, therefore, something which may be always at hand, which is applicable to all ages and thoroughly adapted to the end in view, which is in every particular harmless to the exerciser, which can be used several times daily, and which of itself possesses a sufficient element of interest to insure its long-continued use.

While the varied results of physical training are to be attained at any time prior to middle age, yet the degree of development bears a close relationship to the age of the individual. After the age of fifty, for example, very little increase of lung capacity can be expected; yet, even here, I have noted a decided improvement in the contour of the chest, as well as the acquirement of increased respiratory power. It is during childhood, however, that the greatest successes of physical culture are to be noted, and it is not difficult to understand why this should be the case. All the conditions are at that time favorable for development. The bones and cartilages forming the framework of the chest contain a minimum amount of earthy material, and consequently are extremely pliable. The muscles are undergoing a formative process, and consequently are readily responsive to stimulus and capable of attaining a higher degree of development than at any other time.

The following table, compiled by Roberts, shows excellently well the progressive increase in the circumference of the chest as it occurs normally and without the aid of gymnastic exercise.

Age—Years.	Chest Girth.	Annual Rate of Growth.
	Inches.	Inches
10	23·77	0·50
11	24·33	0·56
12	24·81	0·48
13	26·30	1·49
14	28·18	1·88
15	29·70	1·52
16	31·19	1·49
17	32·80	1·71
18	34·03	1·23
19	34·76	0·73
20	35·13	0·37
21	35·42	0·29

Here it is shown that, although there occurs a progressive growth from early childhood, the greatest increase takes place between the thirteenth and eighteenth years. The increase in height and weight, however, is noted for several years longer. There are other observers who maintain that the lung capacity is increased from the fifteenth to the thirty-fifth year, and at the rate of five cubic inches a year, while after the latter age it diminishes about one and a half cubic inches a year.

Sex exercises some little effect upon growth and development. The investigations of Bowditch have shown that until the age of eleven or twelve years, boys are both taller and heavier than girls of the same age. At this period girls begin to grow rapidly and surpass boys of the same age, in both these particulars. Boys afterward acquire and retain a size superior to that of girls, who have now completed their full growth.

The period of greatest growth is, as a rule, the one most favorable to lung expansion. Hence it follows that between the ages of ten and twenty-five years there is an important interval during which physical development of all kinds may be attained in its greatest degree and with the least labor on the part of the individual. The chest girth of 35·42 inches, as given in the above table, is, therefore, much less than might have been attained had proper chest exercise been employed during the period indicated.

The age at which such exercises should be undertaken depends, of course, upon the condition and surroundings of the individual. Up to ten years or thereabout, a free, active, out-door life, together with such suitable exercises as the schools *should* afford, would be amply sufficient Unfortunately, physical training as ordinarily employed there is a mere farce and scarcely worthy the name. The idea that ten or fifteen minutes of light gymnastics daily is sufficient to strengthen the muscles, straighten the shoulders, and develop the chest is manifestly absurd. One can hardly expect to counteract in a few minutes those influences which are at work from morning till night, or to overcome in a moment physical defects which have existed for years, and perhaps from infancy.

Physical education is deserving of as much recognition in our public schools as any other branch of learning, and not until this fact is realized can we hope to obtain for our children all the essentials of good health and longevity.

Calisthenics, as ordinarily practiced, are, as I have stated, of too trivial a character to produce any very marked results. By allowing children the use of wands or wooden dumb bells varying in weight from a half to one pound, their work is rendered more interesting, and at the same time the improvement in muscular development and conformation of the chest is much more apparent. It may be stated just here that dumb bells, as employed in youth and adult life, are much too heavy. It is seldom expedient to go above five pounds—a weight which will enable one to practice the various exercises for a long time without fatigue. As true chest developers, however, they do not compare for a moment with the weights, for although by their use the chest girth is generally increased, this is most often due to the development of the muscles on the outside of the trunk rather than to increase of lung capacity. The results, therefore, are more apparent than real.

The duration also of these school exercises should be increased. Twenty minutes' work during each of the two daily sessions is not too long, but would produce results far greater and more satisfactory than any heretofore observed.

After the age of ten or twelve years there begins another period which is perhaps more important from a physical point of view than the one preceding it. At this time specific exercises should be instituted for securing lung development. The methods for attaining this object have, I trust, been sufficiently well described. To those who can afford it—and there are very few who cannot—the chest weight offers the most efficient aid. It should be placed in every home in the land where children are, and its daily, routine use should be encouraged and, if necessary, insisted upon. It may at times prove a difficult task to persuade young persons to continue the work they have begun, yet after a habit becomes established, its importance appreciated, and its good effects recognized, all reluctance will most likely disappear.

The object of this paper is the promotion of physical culture, not simply for the improvement of the body or figure, or for purposes of competition, but for the reason that it is one of the chief measures for preventing chronic disease of the lungs. I have endeavored to show that to be most effective, it must be instituted in early life and maintained by proper means through subsequent years. Whatever may be the real cause of consumption, it has been fully established that the well developed lung invariably escapes infection, while the unexpanded one is the first to suffer. Could our educators be convinced of the vital importance of this subject, and be induced to act accordingly, the number of deaths from this disease would be materially lessened, while the capacity for study and for physical endurance would be as greatly increased. During school life the question of the child's future welfare is often decided. It is in the power of parents and teachers to secure for him either a phenomenal brain with a consumptive tendency, or a well developed mind with physical perfection. Now, which shall it be ?—*N. E. Medical Month*.

DR. RICHARDSON ON ALCOHOL.

DR. B. W. RICHARDSON, who is one of the ablest physicians in Great Britain, says: I became an abstainer from alcohol for the most commonplace and selfish reason in the world, the instinct of self-preservation. From a lecture delivered in one of my experimental and practical courses to medical brethren, on December 7, 1869, I infer that I had got, at that time, very near to the practice of abstinence, and quite near to the truth; for I find myself closing the lecture with the following words: "Speaking honestly, I cannot, by any argument yet presented to me, admit the alcohols through any gate that might distinguish them as apart from other chemical bodies. I can no more accept them as foods than I can chloroform, or ether, or methylal. That they produce a temporary excitement is true; but as their general action is quickly to reduce the animal heat, I cannot see how they can supply animal force. I can see clearly how they reduce animal power, and can show a reason for using them in order to stop physical pain, or to stupefy mental pain; but that they give strength, *i. e.*, that they supply material for the construction of fine tissues, or throw force into tissues supplied by other material, must be an error as solemn as it is widespread. The true character of the alcohols is that they are agreeable temporary shrouds. The savage, with the mansions of his soul unfurnished, buries his restive energy under their shadow. The civilized man, overburdened with mental labor, or with engrossing cares, seeks the same shade; but it is shade after all, in which, in exact proportion as he seeks it, the seeker retires from the perfect natural life. To resort for force to alcohol is, to my mind, equivalent to the act of searching for the sun in subterranean gloom until all is night. It is time now for the learned to be precise respecting alcohol, and for the learned to learn the positive value of one of their most potent agents for good or for evil; whereupon, I think, they will place the alcohol series in the position I have placed it, even though their prejudices in regard to it are, as mine are, by moderate habit, but confessed inconsistency, in its favor." I have heard it said many times that this was the strongest utterance I ever made against alcohol; because, when I made it, I was not an abstainer. But I have a word more to add. At the time when the lecture above named was delivered, I had looked only at the physiological side of the matter. Afterward I studied, in the same experimental way, the power of alcohol in producing disease. Thereupon I discovered that so potent is alcohol in producing structural and fatal disease, just as certainly as I could make an animal dead drunk by it, so I could conjure up organic disease to order, if I may so put it, according to my will, and almost according to fixed time and season. Also, I detected that the fatal changes were much more quickly and surely brought about than I had ever supposed possible. I was startled at what I witnessed, and, selfish-like, applied the moral. I said to myself, May be I am experimenting on myself. But why should I? "If thy right hand offend thee, cut it off," was the daily plea of conscientious knowledge; and, at length, the plea prevailing, I cut off alcohol root and branch. Then, when I found how strong and healthy I was, as well as safe, under total abstinence, I thought it my duty, even at the risk of speaking less forcibly against alcohol than I might do if I partook of it—as the spirit of evil suggested—I began and continued boldly to expound all the facts; and that is the way I became an advocate of total abstinence, as well as a total abstainer.—*Hand and Heart.*

THE SOLUTION AND REDEPOSITION OF CARBONATE OF LIME BY SEA WATER.*

IF we turn our attention to the solution of dead carbonate of lime in shells and coral skeletons by the action of sea water, it will be found that the rate of this solution varies greatly according to the conditions in which these remains are exposed to the solvent power of the water. A large number of experiments have been conducted with the view of determining the solubility of carbonate of lime under its different conditions. It may be pointed out that the normal amount of carbonate of lime dissolved in sea water is very small, strikingly so (0 1200 gram. per liter) when compared with the vast amount of this substance continually being secreted from the sea by organisms. Sea water can, however, take up 0 6490 gram. per liter of carbonate of lime in an amorphous (or hydrated) condition, forming a clear supersaturated solution, but after a time not only the excess so added is thrown down, but also sometimes a portion of that normally present in the water itself.

It would thus appear that it is unable permanently to retain in solution more of this substance than is usually found present in sea water. This peculiarity of sea water, after taking up a large amount of amorphous carbonate of lime, and throwing it out in a crystalline form, accounts for the filling up with crystalline carbonate of the interstices of massive corals in coral islands and other calcareous formations, so that all trace may ultimately be lost of their original organic structure. These experiments show a great diversity as to the amount of carbonate of lime which will pass into solution in sea water from various calcareous structures in a given time. As a rule, the more definately crystalline the substance is, the less it is soluble. Calcspar is less soluble than massive varieties of coral, and these again less than the more porous varieties. We have already indicated that amorphous or hydrated carbonate of lime is (in that condition) much more soluble than any other form of the substance. The rate of solution is also much greater when the water is constantly renewed than when the same water remains in contact with carbonate of lime. The water quickly becomes saturated and unable to exert further solvent action.

In this connection we found that different samples of sea water from different localities possessed very different solvent powers. Especially was this the case between summer and winter waters, the former having distinct solvent action on coral skeletons, while with the latter there was hardly any. The lower specific gravity of winter waters may be regarded as to some extent reducing their solvent power, but this is more probably to be attributed to the absence of free carbonic acid, *i. e.*, carbonic acid in excess of what is required to saturate the free base in the sea water as normal carbonate. To test this point, carbonic acid was added to one of these winter waters (which had no solvent action on coral), the quantity added not being sufficient to destroy its alkaline character. It was found that in these circumstances an appreciable amount had been dissolved.

This appears to indicate that there is more carbonic acid in summer than in winter waters in our latitudes, due probably to the increased activity of animal life. Mr. Buchanan's observations on board the Challenger show that the carbonic acid present in sea water, over and above that necessary to form normal carbonate of lime, is subject to great variations. It appears that this is a much more effective agent in the removal of carbonate of lime from shells, etc., than the solvent power of sea water itself (although artificial sea water quite free from carbonic acid dissolves carbonate of lime). Buchanan's observations have also shown that carbonic acid, as a rule, is more abundant in bottom than in surface waters; and Reid's experiments show that carbonated sea water under high pressure takes up more carbonate of lime than that at a normal atmospheric pressure.

The fact that carbonic acid is more abundant in deep waters is evidently connected with the respiration, and also the decay, of the animals which live and die on the ocean floor; and also with the decay of those which fall from the surface. The water filling the deeper hollows has also in its passage to the equator passed over thousands of square miles of this floor covered with living animals, and as this water has a very slow motion, and is but slowly renewed, we would expect an accumulation of carbonic acid and deficiency of oxygen in these abysmal depths. When, therefore, carbonate of lime secreting animals die at the surface of the water and their bodies fall to the bottom, the shell is exposed to solution from the action of the sea water through which it passes, and it may be to that of carbonic acid produced by the decomposition of its own organic matter. If the shell be thin, as in the case of heteropods and pteropods, it may be wholly removed before reaching the bottom, but the thicker shelled varieties tend to accumulate even in depths of 2,000 fathoms, where they are soon covered up by other shells; and being surrounded by sea water already saturated with carbonate of lime, are preserved from solution, and form vast beds of calcareous ooze.

It is found that the amount of carbonate of lime present in such ooze is greater or less according to the depth of water through which the shells pass from the surface to the bottom, and also to the slow renewal of the water in contact with these great lime deposits. In the red clay area the carbonate of lime is almost entirely absent. The deeper waters which cover such areas are more active in the removal of carbonate of lime, not only because of the large amount of carbonic acid they contain, but doubtless to the deoxidation of alkaline sulphates by organic matter, which gives rise to sulphuric acid, etc. At the same time account must be taken of the great pressure at such abysmal depths, and the fact that the substance of the shells being less compressible than sea water, they would fall more slowly, and hence would be longer exposed to the action of the deeper layer of water than those near the surface.

What calcareous remains do reach the ocean floor at such abysmal depths represent the hardest and crystalline varieties of carbonate of lime which resist the solvent action of sea water to the greatest extent.

In this way we appear to have a perfectly rational explantion of the partial disappearance of carbonate of lime shells from the shallower depths, and their total disappearance from all the greater depths of the ocean. It is to be observed that all those shells in which a considerable quantity of organic tissue is associated with the carbonate of lime disappear in solution more rapidly than the shells of the foraminifera, which contain little organic matter. (During the whole of the Challenger cruise only two bones of fishes, other than the otoliths and the teeth, were dredged from the deposits, and all traces of the cetacean bones were removed, except the dense ear bones and dense zyphioid beaks.) The remains of crustacean animals were almost wholly absent from deep sea deposits, with the exception of ostracode shells and the hard tips of some claws of crabs.

Turning now to the lagoons and lagoon channels of coral islands, it is believed that large quantities of carbonate of lime are in the same way being dissolved from these shallow basins as well as from the deposits of the deep sea, but under somewhat different circumstances. In the case of a shell falling to the bottom of the sea, it is continually brought in contact with new layers of water, which has the same effect as if a continuous stream of water were passing over the shell. In the case of the lagoons this last is what takes place. The water which flows in and out of the lagoons twice in twenty-four hours passes over great beds of growing coral, and from all the observations we have is largely charged with carbonic acid, owing probably to the large number of living animals on the outer reef over which the water passes on its way to the lagoon. This water passes continually over the dead coral and sand of the lagoon, and takes up and removes large quantities of carbonate of lime in solution (as well as suspension), for in these lagoons the spaces covered by dead coral *debris* always greatly exceed the patches of growing coral. Owing to the fact that the water of the lagoon is continually in motion and constantly renewed, the layer in contact with the bottom of coral sand can never become saturated or unable to take up more lime, as is apparently the case in the layers of water in contact with the globigerina ooze and other calcareous deep-water deposits.

From the foregoing discussion and observations it is evident that a very large quantity of carbonate of lime is in a continual state of flux in the ocean; now existing in the form of shells and corals, but after the death of the animals passing slowly into solution, to go again through the same cycle.

On the whole, however, the quantity of carbonate of lime that is secreted by animals must exceed what is redissolved by the action of sea water, and at the present time there is a vast accumulation of carbonate of lime going on in the ocean. It has been the same in the past, for with a few insignificant exceptions all the carbonate of lime in the geological series of rocks has been secreted from sea water, and owes its origin to organisms in the same way as the carbon of the carboniferous formations; the extent of these deposits appears to have increased from the earliest down to the present geological period.

At the present time most of the carbonate of lime carried to the ocean by rivers has been directly derived from calcareous stratified rocks formed by organic agency in the sea in earlier geological ages, but the calcium in these formations was, in the first instance, derived from the decomposition of the lime-bearing silicates of the earth's original crust, and this decomposition, which is still going on in the sea and on the land surfaces, is a continuous additional source of carbonate of lime.

In considering the analyses showing the average composition of sea salts, one is struck with the relatively small quantity of those very substances which are extracted so largely from sea water by plants and animals, viz., carbonate of lime and silica. Siliceous deposits are of vast extent, yet silica occurs merely in traces in sea water; carbonate of lime deposits are of vastly greater magnitude, yet carbonate of lime makes up only $\frac{1}{130}$ part of the saline constituents of sea water, and only $\frac{1}{8300}$ part of the whole bulk of sea water. Sulphate of lime is ten times more abundant than the carbonate in sea water; on the other hand, the river water that is poured into the ocean contains about ten times as much carbonate as it does of sulphate of lime.*

The total amount of calcium in a cubic mile of sea water is estimated from analyses to be 1,941,000 tons, and the total amount of calcium in the whole ocean is calculated at 628,340,000 000,000 tons. The total amount of calcium in a cubic mile of river water is estimated at 141,917 tons, and the total amount of this element carried into the ocean from all the rivers of the globe annually is estimated at 925,866,500 tons. At this rate it would take 680,000 years for the river drainage from the land to carry down an amount of calcium equal to that at present existing in solution in the whole ocean. Again, taking the Challenger deposits as a guide, the amount of calcium in these deposits, if they be 23 feet thick, is equal to the total amount of calcium in solution in the whole ocean at the present time. It follows from this that if the salinity of the ocean has remained the same as at present during the whole of this period, then it has taken about 680,000 years for the deposits of the above thickness, or containing calcium in amount

* From a paper by Messrs. J. Murray and R. Irvine, read before the Royal Society of Edinburgh.

* Murray, "Total Rainfall of the Globe," *Scot. Geogr. Mag.*, 1887,