were analyzed. The quality of these waters and the source of their mineral content are discussed in the report.

It is thus apparent that the reconnaissance has yielded results that are important contributions to the geologic history of the West Indian region. It has also yielded results that in many ways have an intimate bearing on the welfare of the inhabitants of the Republic—results based on an understanding of the geologic features derived from observations that at first glance may seem to be of purely scientific interest only.

BIOLOGY.—*The origin of the vertebrates.* AUSTIN H. CLARK, National Museum.

Heretofore all the writers on the subject of the evolution of the vertebrates have approached the problem with the complex vertebrate structure admittedly or unconsciously dominating the perspective within which all other types of animal structure should fall. Under the influence of this preconceived though unconfessed idea either a devious line was traced from the vertebrates through progressively simpler forms eventually ending in the protozoans, or a line was drawn from the protozoans to the vertebrates from which more or less numerous side branches were given off terminating blindly in supposedly anomalous types.

It never seems to have been noticed that animals and plants are but slightly different manifestations of the same organic phenomena, and that therefore there is no reason to suppose that the evolutionary line in one kingdom would be in its broader features greatly different from that in the other.

In the following pages I shall attempt to show that if we consider the phanerogam-like radially symmetrical colonial coelenterate type as representing the culmination of animal evolution properly so called, and the bilateral animals as having arisen through the disruption of this type and the gradual geometrical recombination of the characters of the forms resulting from this disintegration, we shall have an explanation of the origin of all the different animal types by which each and every one is allocated and shown to be a necessary element in the general plan.

The embryological processes common to all animals show that the egg develops into a blastula which subsequently becomes a gastrula; but from this point onward the developmental processes exhibit no features common to all animal types.

The gastrula, present in the ontogeny of all animals, is the last structural complex which is of universal occurrence throughout the animal kingdom and the last common bond between the various animal types, and it therefore must in some way represent the starting point for all subsequent divergence.

An egg typically divides into two, four and eight cells in three planes each of which is at right angles to the other two and, equal cell division continuing, a hollow sphere is formed, the blastula, which collapses, forming a more or less hemispherical structure with two layers of cells, an outer and an inner, the gastrula.

The gastrula possesses a single axis which runs through the center of the opening resulting from the collapse of the blastula; but since the walls of the gastrula are everywhere the same there is a perfect radial symmetry about this axis.

Since the gastrula, though usually in a considerably modified form, is common to all animal types and forms the starting point for the divergence of the various major groups, it is important to determine what its real significance is.

From the egg through the blastula to and including the gastrula there is a direct geometrical continuity leading to the formation of a body radially symmetrical about a single axis. The logical termination of such development would be the formation of an animal type in which the gastrula axis persists to the adult and the body of the adult is radially symmetrical about it.

If the facts presented by a study of embryology are significant in indicating the phylogeny of animals, it is clear that the last common ancestor of all the bilaterally symmetrical animal types was a radially symmetrical form, or a sort of adult gastrula.

There are two such animal forms. In one of these, the sponges, the body consists of a community of cells imperfectly integrated and showing relatively little devision of labour or unified life. The sponges continue to grow throughout life, and their increase is always radial.

In the other, the coelenterates, the body is a distinct unit of more or less definite size with a gastrovascular cavity and a well developed muscular system. Growth in the coelenterates as in the sponges is continuous throughout life; but since the complexity of the organization imposed a definite maximum size on the individuals, the growth impetus results in the continued formation of new individuals which bud off from those preceding, typically resulting in an arborescent or mass colony comparable to that seen in the phanerogams. While in many coelenterates the budded individuals become free, and in some there is no budding at all, there can be no doubt that fundamentally the coelenterates are phanerogam-like colonial animals.

There is nothing that can be assumed to connect the sponges with any other animal type except, perhaps, with certain of the Protozoa. It is evident that the gastrula stage in the development of the bilateral animals cannot represent any sponge-like progenitor. It is possible, however, to interpret the bilateral animals in terms of the colonial coelenterate. Indeed, it is not possible to interpret them in any other way, for any other explanation of their origin would assume the presence of a fundamental bilateral tendency, an unknown and undeterminable variable not common to all animal types.

If a colonial coelenterate with radially symmetrical polyps should develop a persistent defect in the ontogeny whereby the units became bilaterally symmetrical, bilateral animals of four main types would at once appear:

1. Bilateral animals in the form of a linear more or less unified colony.

2. Bilateral animals in which the colony formation was inverted, the budding of the new elements taking place within the original unit.

3. Bilateral solitary animals each representing a dissociated coelenterate unit; and

4. Bilateral animals with the colonial habit, though independent of each other.

These four main types, between which there would be numerous intergrades, all represent definite types occurring among the coelenterates themselves, and therefore none of them can be said actually to represent anything new in animal structure other than the novelty consequent on the developmental defect which resulted in the loss of the radial and the assumption of the bilateral body form.

Among the animals of today all four of these main types are represented:

1. The tape-worms or segmented cestodes form a linear colony of continuous growth so like a partially unified strobila as to leave little doubt of the fundamental similarity of type. The scolex of the cestodes is radially symmetrical, but the proglottides are strongly flattened and bilaterally symmetrical, though the difference between the dorsal and the ventral surface is but little marked.

2. The flukes have a peculiar development which is essentially similar to strobilization, except that the buds are formed within the original unit instead of in a linear series.

In those coelenterates with division of labour the polyps are of three sorts, (*a*) nutritive, or sac-like, (*b*) reproductive, and (*c*) excretory, or "defensive." If in strobilization of the fluke type buds of each of these sorts were formed internally, this would furnish the elements necessary for the creation of the so-called coelome, which is divided into three parts, (*a*) the perivisceral, or sac-like, (*b*) the gonadial, and (*c*) the excretory or nephridial.

The flukes and their allies always retain distinct traces of radial symmetry, especially in their digestive system and in the arrangement of their nerves.

3. The turbellarians and nematodes are bilateral solitary animals, the individuals each comparable to a single coelenterate polyp. All of them show distinct traces of radial symmetry in their nervous system, and the turbellarians also in their digestive system.

4. Such turbellarians as *Microstomum* are single animals each comparable to a single coelenterate polyp; but they divide in such a way as to produce chains of similar attached animals each of which is independent of the others and not a part of a more or less unified entity as in the case of the proglottides of the tape worms.

The cestodes, the flukes, the turbellarians and *Microstomum* are all flat worms and all more or less closely related to each other. They all retain to a very considerable degree traces of radial symmetry and of other coelenterate features. Being intermediate between radially symmetrical and bilaterally symmetrical types it requires very little imagination to assume that they represent the four original types into which the coelenterates disintegrated upon the appearance of that developmental defect which resulted in bilateral symmetry.

If the preceding suppositions are logical it is evident that the so-called evolution of the bilateral animals cannot be evolution in the sense of the progressive development of higher types from lower, but instead must have been a recombination and reassortment of the four diverse features characteristic of the four types into which the radially symmetrical colonial coelenterate type disintegrated. In other words the so-called evolution of animals is in reality a convergence toward a common centre from four equidistant points, and the progressive economic efficiency does not indicate any real phylogenetic progress, but results merely from a more and more intimate intermingling of, and a progressively better balance between, the main features indicated by the tape worms, flukes, turbellarians and *Microstomum* standing at the four corners of the original square.

The four corners of this square are marked by four animal types which are closely related to each other, yet at the same time are fundamentally distinct. One of them indicates the commencement of the segmented body; another shows the beginnings of the coelomic structures; a third is simple, with no indications of segmentation or of a coelome; while the fourth is a colonial form of the third.

From these four points there would proceed evolution of two kinds. Each type would give rise to all economically possible variants through a process of continuous development which could be approximately represented by a branching tree-like figure; but all of the the different forms arising in this fashion would fall strictly within limits of its proper type.

As examples of such evolution may be mentioned the insects, crustaceans, molluscs, annelids, etc., within which groups all the included types may be more or less successfully represented as branches of a tree-like figure at the base of which lies a generalized or primitive form; but this and all the others however much they may diverge in details of structure always agree in their fundamental features.

Since they all have arisen from the same colonial coelenterate-like ancestor which has, so to speak, exploded into four different types, each of these four points represents an animal complex in a state of unstable equilibrium; for each one has latent within it the fundamental features of the other three.

Such an unstable equilibrium, in effect an explosive force, would presumably result in a sudden readjustment of the somatic balance whereby intermediate types would appear, one between each two of the four corners (fig. 1); while these intermediate types, each a distinct re-creation and not genetically connected with either of its neighbors, would show a distinct economic advance, this economic advance would in no way represent real evolutionary progress, for it would be merely the result of the combination of the advantages inherent in the structure of the types on either side.

Thus there would suddenly appear, quite without apparent ancestry, (1) segmented animals, like the tape-worms, with a coelome, like the flukes; (2) unsegmented animals, like the turbellarians, with a coelome like the flukes; (3) solitary unsegmented animals without a coelome, like the turbellarians, but with abundant asexual reproduction, like *Microstomum:* and (4) segmented animals without a coelome, like the tape-worms, but less unified and without the continuous loss of the units, as in *Microstomum.*

All four of these intermediate types actually occur. All are entirely and widely distinct from each other, and show no demonstrable intergradation with any of the remaining animal types, each occupying a markedly isolated position. Three of the four are extraordinarily rich in genera and species; the last and least successful is represented by two closely parallel and non-intergrading forms which are identical with regard to the features with which we are concerned, but differ in all others. One of the first three is the only major animal group which has not persisted to the present time.

The segmented animals with a coelome are the annelids; the unsegmented animals with a coelome are the priapulids and sipunculids;

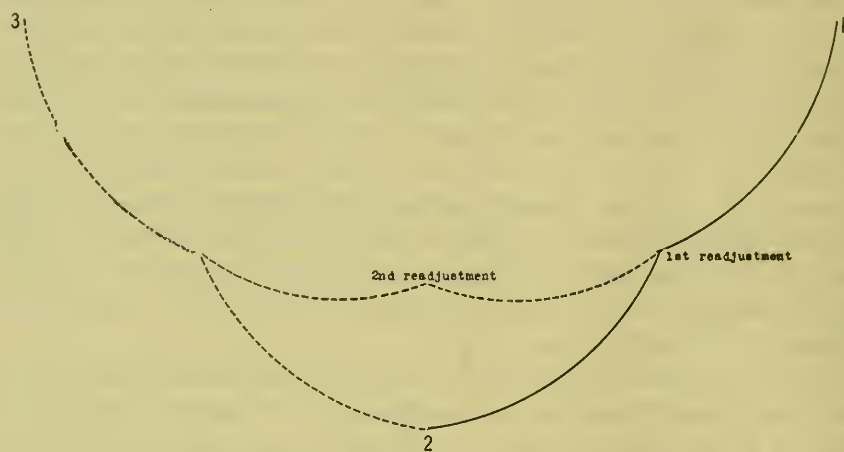

Fig. 1. Showing the first and second readjustments.

the solitary acoelomate animals with abundant asexual reproduction are the rotifers; and the acoelomate animals forming colonies of separate individuals are undoubtedly the graptolites (fig. 3).

Through this readjustment as just described each of the new animal types would combine the features of two of the original types. But since in each of these new types two of the four chief features are absent, there would still exist a condition of unstable equilibrium as compared with the colonial coelenterate-like ancestor.

A second readjustment of the same nature as the first would be inevitable by which four animal types would appear in line with the first, but combining the characters of the intermediates in the second series (fig. 1).

Three such intermediates (fig. 3) seem to be clearly indicated in the polyzoans, colonial and not at all or very imperfectly coelomate, between the rotifers and the graptolites; the arthropods, with a segmented body like that of the annelids, but divided into two or three units showing division of labour (in the insects one controlling and directing, one locomotor, and one performing the digestive, reproduc-

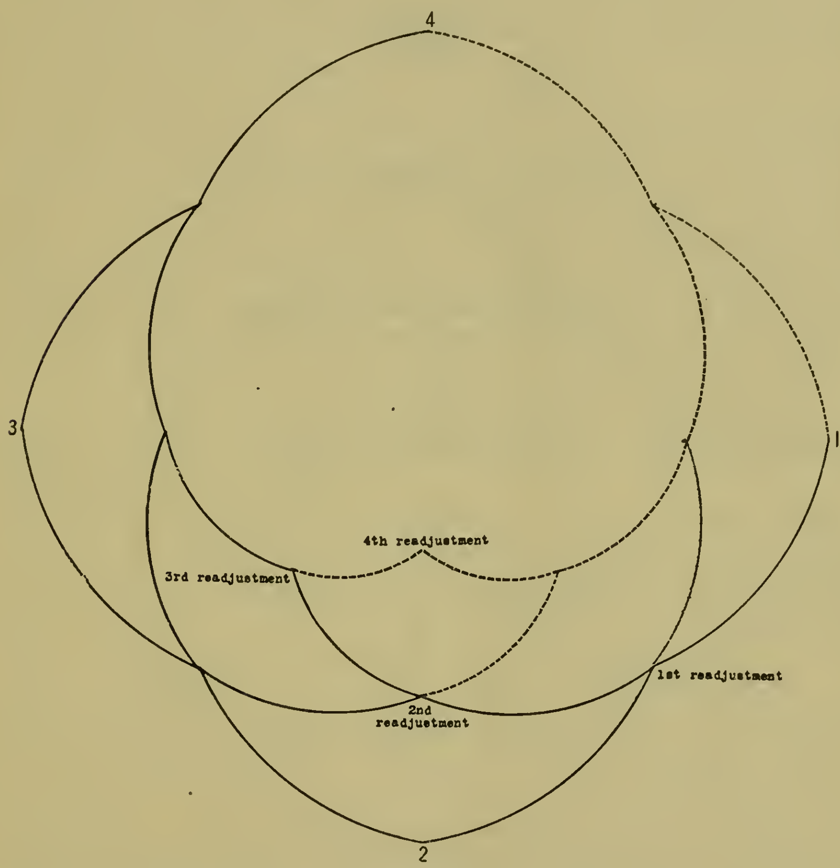

Fig. 2. Showing the first to the fourth readjustments.

tive and other vital functions) after the graptolite or polyzoan fashion, with a poorly developed coelome, with abundant traces of asexual reproduction (polyembryony, parthenogenesis, fragmentation of larvae, etc.), with a marked tendency to form (as in the ants) polyzoan-like colonies with division of labour among the (dissociated) units, and sometimes even forming dendritic colonies (as in *Thompsonia*); and the molluscs, always solitary, like the priapulids and sipunculids, with a highly developed coelome, and with traces of segmentation suggesting the annelids. The fourth group should be solitary with an indication of colonial structure and a coelome, but without segmentation. It is possible to place the nemerteans here by assuming their imperfect segmentation to be of the *Microstomum* and not of the tape-worm type.

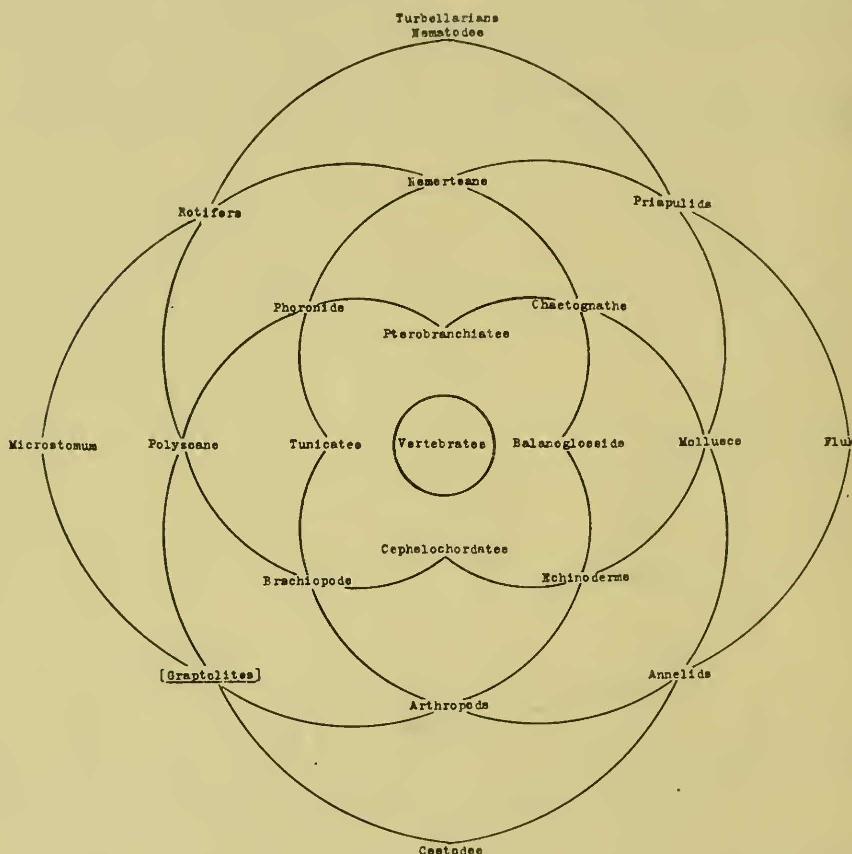

Fig. 3. Showing the development of the various animal types above the coelenterates.

There is still a condition of unstable equilibrium, for in each of these four groups one of the original elements is lacking. A third readjustment (fig. 2) would be necessary to recombine all the main features characteristic of the original four types.

Four animal groups (fig. 3) appear to be the result of such a readjustment. The echinoderms combine a reduced body consisting of five half segments of the arthropod type with a highly perfected coelome; the chaetognaths suggest a relationship with the molluscs, and also with the nemerteans; the phoronids suggest a relationship with the polyzoans, but have a well developed coelome, and the colonial habit is reduced to the budding off of new individuals; and the brachiopods suggest both the polyzoans and the barnacle-like arthropods.

While by this third readjustment all the four original features are recombined in each animal type, the balance between them is imperfect, for the influence of one of these features in each case is greatly overshadowed by the influence of the other three.

A fourth readjustment (fig. 2) would correct this imperfect balance and result in the appearance of four animal types all very much alike.

There are four types which appear to belong here (fig. 3), the tunicates, the cephalochordates, the balanoglossids and the pterobranchiates. The tunicates seem to be in line with the polyzoans, while they also suggest both the brachiopods and the phoronids; the cephalochordates clearly stand in the cestode-arthropod line, and at the same time show indubitable affinities with the echinoderms; the balanoglossids, with no trace of asexual reproduction, may be considered in line with the flukes and molluscs and between the chaetognaths and echinoderms; while the pterobranchiates seem to fall between the chaetognaths and the phoronids.

These four closely related types resulting from this fourth readjustment are each slightly excentric; but they are so close to each other that a fifth readjustment would presumably give a final perfected type in which at last all of the four chief features of the original types would be reunited in the economically most perfected form.

The vertebrates appear to occupy this central position (fig. 3). In them we are able to recognize the segmentation of the cestodes, annelids, and cephalochordates, combined with the coelomic structure first indicated in the flukes, both enclosed in the undivided body of the turbellarians. Unless the limbs can be compared to budded units recalling certain highly reduced and specialized units in tunicate or polyzoan colonies, the influence of the feature represented by *Microstomum* seems to have disappeared.

In the course of the various readjustments which culminated in the formation of the vertebrates numerous secondary features, such as visual and other sense organs, appendages of different kinds, diverticula and other outgrowths from the enteric canal, chitinous and calcareous skeletons, etc., all of which exist in the coelenterates and in one or other of the four types derived immediately from them, became enormously developed and specialized in correlation with the increasing bodily efficiency resulting from the recombinations. But if the analysis of the origin of the various animal types just given is an approximately true exposition of the facts, the vertebrates, in spite of their wonderful complexity of structure and their very high degree of efficiency, represent nothing more than the final recombination of characters already occurring in the colonial coelenterates which were widely dissociated at the inception of bilateral symmetry.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

877TH MEETING

The 877th meeting was held in the Cosmos Club Auditorium on Saturday, January 27, 1923. The meeting was called to order at 8:15 P.M. by President White with 29 persons in attendance.

Mr. G. T. Rude presented a paper on *Instruments and methods for the observation of tides.* The paper was illustrated with lantern slides, and was discussed by Messrs. Lambert, Bowie, Pauling, Humphreys, Hawksworth, Faris, Littlehales, and Tuckerman.

Author's abstract: A continuous record of the rise and fall of the tide is necessary in connection with a number of engineering and scientific problems.

The simplest method of tidal observation consists in observing the changing height of the water as noted on a fixed vertical staff. From this it was but a step to devising some mechanical means for recording automatically the rising and falling of the surface of the sea.

The earliest automatic tide gauge of which we have record was devised by an English civil engineer, Henry R. Palmer, and is described in the Philosophical Transactions of the Royal Society, London, for the year 1831.

Of the automatic tide gauges, two classes may be recognized: (1) those in which the changes in elevation are shown in the form of a curve; (2) those in which the height of the water at definite intervals is shown by means of figures, or the so-called printing gauges. The various forms of the tide gauges in use were shown by means of slides and attention called to the distinguishing features.

Special attention was directed to a new type of automatic tide gauge recently developed in the office of the Coast and Geodetic Survey for use of hydrographic parties in the field. In designing this instrument the objects sought were ease of installation and minimum size commensurate with the desired accuracy. The gauge is about 10 inches long and 9 inches high. The clock is placed inside the cylinder carrying the cross-section paper on which the curve of the tide is drawn. No counterpoise weight is used, a coiled spring taking the place of the weight. The float well is ordinary 3½ inch stock iron pipe and in addition to serving as a float, it acts as a support for the gauge. No platform is necessary for the installation of this gauge, which may be lashed to a pile on a bar or to net stakes in bays or rivers. A metallic cover furnishes the only shelter necessary.