in more advanced subjects be included in the undergraduate curriculum?'

PROFESSOR F. MORLEY: 'Certain phases of the general question.'

PROFESSOR J. W. A. YOUNG: 'Collegiate preparation for the teaching of mathematics in secondary schools.'

A general discussion of the subject then took place.

On each evening of the meeting, the members generally took advantage of the opportunity to dine together.

The next regular meeting of the Society will be held in New York on Saturday, October 27th.

F. N. COLE,
Secretary.

THE RELATION OF BIOLOGY TO PHYSIOGRAPHY.

THE studies of paleontologists have been among our chief sources of information concerning the physiography of various regions in past geologic periods. Far-reaching conclusions have been drawn from faunal resemblances and differences as to the relations of sea and land, the presence or absence of barriers and the direction of marine currents during particular epochs of the earth's history. It is evident that biology should bear a relation to physiography analogous to that which paleontology bears to paleophysiography. Some of the ways in which the two distinct sciences react upon each other have been pointed out by Woodworth,* and it is the purpose of the writers to call attention to a specific case in point where identical conclusions were reached quite independently by different investigators pursuing distinct lines of research.

These results are of the utmost importance in the particular problems upon which they bear, but their chief value at the present time lies in the fact that they bring physiography and biology upon common ground and show that each may and should receive assistance from the other.

In discussing the origin and recent history of the physical features of the southern Appalachians* in 1894 the writers advocated the theory that the upper Tennessee River formerly flowed into the Gulf of Mexico by way of the present Coosa and Alabama rivers, and that it was diverted to its present course through the Cumberland Plateau in the latter part of Tertiary {Neocene (?)} time. The former course of this river is shown on the accompanying outline map by the dotted line *A* which extends in the direction of the upper Tennessee from the vicinity of Chattanooga southwestward to the Coosa in eastern Alabama.

This theory was again advocated by the senior author† in 1897–98, and the evidence in its support was presented in somewhat greater detail. The conclusions in both reports were based entirely upon physiographic evidence—such as the character of the Tennessee—Coosa divide, the newness of the gorge below Chattanooga and the general arrangement of the drainage lines.

We recently learned with considerable surprise and gratification that Mr. Charles T. Simpson, of the Smithsonian Institution, had independently reached the same conclusion from a study of the fresh water mollusca contained in the rivers in question.

In an equally unexpected manner Mr. Simpson has corroborated the conclusions of the junior author‡ regarding the changes which have taken place in the head branches of the Coosa, Chattahoochee, and Savannah rivers.

The conclusion that the Etowah River had been robbed by the Chattahoochee

* J. B. Woodworth, 'The Relation Between Base-leveling and Organic Evolution,' *Am. Geol.*, Vol. XIV., pp. 209–235, 1894.

* Geomorphology of the Southern Appalachians: *Nat. Geog. Mag.*, Vol. VI., pp. 63–126, May, 23, 1894.

† Physiography of the Chattanooga District. 19th Ann. Rept., U. S. Geol. Survey, Part II., pp. 1–58.

‡ Drainage Modifications and their Interpretation. *Jour. Geol.*, Vol. 4, pp. 567–581 and 657–673.

River was based upon the following facts: (1) the lowness of the divide at Dahlonega, Georgia between the Etowah River and a branch of the Chattahoochee River; (2) the similarity of the alignment of the beheaded portion with that of the remaining Etowah River, as shown at *B* on the map and (3) the plainly apparent tendency of the southeastward flowing streams to encroach upon their neighbors on the northwest in all the territory about the headwaters of the three rivers in question. This change was supposed to have taken place when the surface relief was slight, presumably on the elevation of the Tertiary peneplain above baselevel.

The conclusion that the upper course of the Chattahoochee River has been transferred to the Savannah system by diversion near Tallulah Falls, at the point marked *C* on the map, was based on similar grounds, but in this case the proof is stronger for the southeastward flowing streams show even a greater tendency to encroach toward the

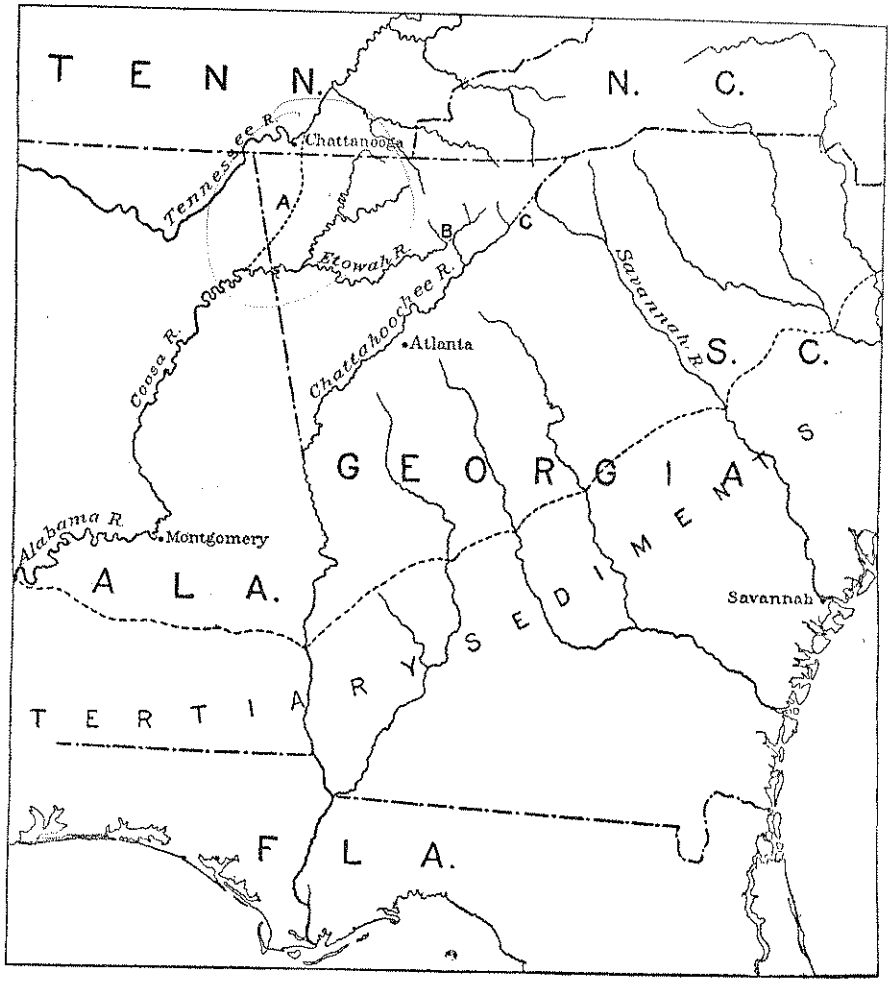

Fig. 1. Drainage map of the Southern Appalachian region, showing recent stream diversions. Hayes and Campbell.

northwest than they do in the vicinity of Dahlonega.

Thus the purely physiographic evidence shows that there was a former connection between the upper Tennessee River and the Coosa system by which the molluscan fauna could easily pass from one to the other. It also shows conclusively that a part of the Etowah River has been transferred bodily to the Chattahoochee system. Such a wholesale shifting of divides would result in the transference of such of the Coosa-Tennessee forms as then existed in the headwaters of the Etowah River.

This infusion of new forms spread throughout the Chattahoochee system, even to its headwaters, but the foreign types presumably constituted only a small proportion of the existing fauna. When the Savannah River cut through the divide and captured the upper part of the basin of the Chattahoochee, it carried with it a limited number of forms belonging to the Coosa-Tennessee type. Thus in each successive transfer the percentage of the original forms has grown less and less, until in the Savannah River, as reported by Mr. Simpson, they are scarcely recognizable.

Beyond Savannah, toward the northeast, none of the peculiar Tennessee forms have been found, nor is there any indication in the surface configuration of there having been any drainage changes of consequence in this region.

In most respects the biological evidence simply corroborates the conclusions based upon a study of the surface features, but in the question of age relations it throws some new light upon the problem. The migration of Coosa-Tennessee fauna from west to east shows conclusively that the changes in drainage must have followed a similar order, hence the diversion at Dahlonega must have preceded that which occurred near Tallulah Falls. This important fact presumably could never have been determined from the physiographic evidence alone.

Throughout the whole region there is a surprisingly close agreement between the biologic and the physiographic evidence which clearly indicates that biology should stand in the same relation to physiography that paleontology does to paleo-physiography.

The following brief statement of the evidence on which Mr. Simpson bases his conclusions was prepared at our suggestion for publication in advance of the more detailed report which the author has in preparation.

C. W. HAYES,
M. R. CAMPBELL.
U. S. GEOLOGICAL SURVEY.

ON THE EVIDENCE OF THE UNIONIDÆ REGARDING THE FORMER COURSES OF THE TENNESSEE AND OTHER SOUTHERN RIVERS.

SEVERAL years ago while studying the life history and distribution of the Unionidæ, or Pearly Fresh Water mussels I was struck by the close relationship existing between that part of the mollusk fauna of the Tennessee River drainage system and that of the Alabama.

Within the Mississippi drainage basin there is found the richest and most wonderful, as well as the most highly developed Unione fauna of any part of the world. Perhaps not less than 400 species, at a most conservative estimate, are found in this area. The Unione fauna of the Tennessee drainage system (including that of the Cumberland) contains a very large proportion of the species found throughout the Mississippi area, and in addition to these a great many peculiar species found nowhere else in the Mississippi system. The genus *Pleurobema*, as I have defined it, a large group of forms having rather heavy, triangular shells, generally tawny colored, with broken, green rays, has its metropolis in the Tennessee

area. Only three species of the genus occur in the Ohio River. Two of these Ohio River species extend west into and across the Mississippi, but I know of no form belonging to the genus that is found in any part of the lower 300 miles of that stream, in the Pearl or the Pascagoula rivers, or any of the small rivers in Mississippi or Louisiana flowing into the Gulf. No member of the genus is found in any of the streams flowing into the Atlantic (with possibly a single exception).

Yet the entire Alabama River system is filled with *Pleurobemas*. There are many of them in the Tombigbee and Black Warrior, still more in the Alabama itself, and the Coosa swarms with them. But not a species of *Pleurobema* found in the Alabama River area is identical with any found in the Tennessee system. Those of the latter drainage area are, for the most part, very closely related to each other, and belong to a single great group typified by the well known *Unio clavus* of Lamarck. There are several closely related groups of *Pleurobema* found in the Alabama system, and all these are nearly related to the *clavus* group, yet no member of the latter group is found in the southern drainage, and no member of any of the southern drainage groups is found in the northern drainage.

There are a number of Uniones which have a somewhat general distribution in the Mississippi area including the Tennessee system, that are found in the Alabama River drainage, such as the *Unio tuberculatus*, of Barnes, *U. ebenus* Lea, *U. multiplicatus* Lea, *U. cornutus* Barnes, *U. pustulosus* Lea, *U. rectus* Lamarck, *U. trigonus* Lea, and *U. obliquus* Lamarck. There are others which are only found in the Tennessee and Alabama systems such as *U. cumberlandicus* Lea, *U. conradicus* Lea, and *U. varicosus* Lea; the latter, however, extends into the Ohio River.

Yet all these which occur in the Alabama and its branches have some slight characters by which they differ from the same species when found in the Tennessee; not enough to separate them specifically or perhaps varietally from each other, yet an expert will generally be able to tell at a glance from which system a given specimen has been obtained. *Unio gibbosus* of Barnes, an abundant, widely distributed and variable Mississippi drainage species, is found in the Alabama system, but it is shorter, smaller and more humped than the type, and Dr. Lea believing it to be a valid species called it *Unio subgibbosus*. I believe that it is only a variety or geographical race of *U. gibbosus*. *Unio poulsoni* Conrad found in the Alabama River is, I am sure, only a variety of the *U. alatus* Say, a species widely distributed in the central part of the United States.

A few species of *Pleurobema*, and certain species of other genera of Unionidæ closely related to forms found in the Mississippi valley, and evidently derived from the fauna of that region are found in the Chattahoochee, the Flint River, and some of the streams of Southeastern Alabama.

In the streams draining into the Atlantic from Labrador to Georgia there is found everywhere a group of Unios typified by *Unio complanatus* Dillwyn. There are a great many forms belonging to this group which have received specific names at the hands of authors, many of which are, apparently, only mere variations of a few leading forms and not worthy of even varietal names. Quite a large number of forms belonging to this group also occur in the Chattahoochee River system, some of which appear to differ a little from the Atlantic drainage species while others do not seem to be specifically different. Many of the forms of this group in both the areas mentioned seem to be merely incipient species and the synonymy is in a hopeless tangle. *Unio columbensis* Lea, a member of the *Tetra-*

lasmus group of Unios, found abundantly in the Chattahoochee River, can hardly be separated from forms of *Unio obesus* Lea, found in the streams of the Atlantic drainage from North Carolina to Florida. Two or three members of the *Buckleyi* group of Unios seem to inhabit both the Chattahoochee River and its branches, and the Savannah River and nearby streams of the Atlantic drainage. One member of this group, *Unio tortivus* Lea, is common to certain streams flowing into the Atlantic, a considerable part of Florida, the Chattahoochee River system and the Black Warrior River, in Alabama.

These remarkable facts of Unione distribution led me long ago to believe that at a former period, during the lifetime of some of the present species of Unionidæ, sometime in the middle or later Tertiary, perhaps, the Tennessee River must have flowed southward into some one of the streams of the Alabama drainage, and through this discharged its waters into the Gulf of Mexico. It seemed most likely that this connection was by way of the Coosa on account of its nearness to Tennessee, and because the genus *Pleurobema* is more abundantly represented in that river than in the Cahawba or Black Warrior. It seemed likely, too, that during this or some nearby time there had been for a limited period connection between the waters of the Tennessee and the Chattahoochee system, either directly across to the upper part of the latter, or in some way by the Alabama system. I could account for the distribution of these forms of life in no other way, because they cannot travel overland from river to river, but must have water communication in order to pass from one stream to another.

I concluded that the connection of the Tennessee with the Alabama drainage had been severed permanently, certainly as far back as the later Tertiary. That the *Pleurobemas* being somewhat susceptible to the influence of environment had changed until new though closely allied groups had been developed in the Alabama region since the Tennessee began to flow into the Ohio; that other species of southern drainage had developed from closely allied ancestors of northern origin. Others less susceptible to environmental influence had only changed to new varieties in their new location, while still others in which the characters were firmly fixed only changed slightly in appearance.

Although it is possible that forms of the *Complanatus* and other groups of Unios might have migrated from the Atlantic along the low shores, of a former strait in upper Florida connecting that ocean with the Gulf of Mexico, and from thence up the Chattahoochee River system, yet it would seem more likely that these had passed from the Savannah to the Chattahoochee River by water connection at or near the head of these two streams which have their sources very near together.

In this brief sketch I have not gone exhaustively into the evidence presented by the Unionidæ. There are many other species found in the Alabama River system which are evidently identical or nearly related to Tennessee River forms, but which have no very close relationships with the species of any other region and which are, most likely, descendants of Tennessee forms. In fact it is probable that nearly all the Unionidæ of the Alabama River system have been derived from the Tennessee.

This subject will be discussed to some extent in my forthcoming synopsis of the Naiades.

These conclusions almost exactly coincide with those arrived at by Messrs. Hayes and Campbell, who have made a very careful and exhaustive study of the geomorphology of the Southern Appalachians. And it is indeed interesting that the geologist and biologist, though working along entirely different lines, should have met on common ground.

C. T. Simpson