mits the addition of new material or the rearrangement of the exercises to conform to any desired order of presentation.

Although trigonometry is not used, which may be regretted by some teachers, the exercises are not too elementary. The questions which accompany each exercise are especially well chosen and demand considerable thought on the part of the student. The explanations and instructions to students are admirable for their clearness and completeness, and should reduce personal supervision to a minimum.

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SPECIAL ARTICLES

ON THE DIFFICULTIES ENCOUNTERED IN THE EVOLUTION OF AIR-BREATHING VERTEBRATES

GEOLOGISTS and paleontologists have noticed and commented upon the relatively late origin of the air-breathing forms of animals, meaning thereby, as I understand the situation, the animals which can range freely at a considerable distance from the water. Some have attributed this late origin to the presence of high concentrations of carbon dioxide in the early atmosphere, so high, in hypothesis, as to preclude respiration in the atmosphere. When one compares the relative solubilities of carbon dioxide and oxygen in water at ordinary temperatures, it is a bit difficult to see how aquatic or marine forms would be very much better off as regards the presence of oxygen or the absence of carbon dioxide than the terrestrial forms. Chamberlin,[1] dissents from the view that high concentrations of carbon dioxide in the atmosphere prevented or delayed the appearance of land forms, and regards their late origin as due to the difficulties encountered in their evolution. I am inclined to agree with Chamberlin, as the difficulties to be overcome by these forms seem considerably greater than has been realized by either comparative anatomists or paleontologists. Some months ago, I[2] presented a short summary of my views on the organization of the nervous mechanism for the control of respiratory movements. The full data on which these conclusions were based have not yet been published, and the survey of the phylogenetic development of the respiratory mechanism is not yet finished, but some further conclusions bearing on the origin of the air-breathing vertebrates seem fairly clear. In view of their paleontological as well as physiological interest, I wish to make a further brief statement at this time.

[1] Chamberlin, T. C., *Journal of Geology*, 1897, V, 653.

[2] Pike, F. H., and Coombs, Helen C., SCIENCE, 1922, LVI, 691–693.

It is apparent that the respiratory mechanism of vertebrates has undergone more profound and far-reaching changes in the transition from aquatic to air-breathing forms than any other functional mechanism of the organism unless we except the central nervous system itself. The development of lungs has received much attention from comparative anatomists and paleontologists, but the development of lungs has supplied only a part of the new mechanism which was necessary. The respiratory muscles of fish are mainly those of the mouth or the special branchial muscles of the neck. So far as inspiration goes, these same muscles, or their lineal descendants, in the mouth are still functional in the amphibia which possess lungs. No conflict between food swallowed and respiratory medium taken into the mouth —water containing air in solution—occurs in fishes. With the development of an offshoot of the esophagus as an air passage in the frog, a coordination of the swallowing and the respiratory movements becomes necessary to prevent the entrance of food into the trachea and the air passages generally. This need becomes greater rather than less in successively higher types of vertebrates. The coordination of these two acts (swallowing and respiratory movements) requires the development of a special nervous mechanism which, so far as I am aware, does not exist in fish. The muscles of the flank and abdomen of the frog have some expulsive or expiratory action, but no true inspiratory action. It is only when the reptiles are reached that we find the muscles of the body wall acquiring a true inspiratory function. The frog, depending upon the muscles of the floor of the mouth for forcing the air into the lungs, can not take air into the lungs while holding the mouth open. Its food is limited to such things as it can swallow without holding the mouth open too long. The serpents, because of their ability to draw air into the lungs through the action of the muscles of the body wall, may swallow animals of considerable size, taking their leisure for the process and pausing to breathe when necessary. Though many of the reptiles still remain near the water, or even live in it most of the time, it is among these forms that we find the first animals which can live far from the water for relatively long periods. Lastly, we find in the mammals the final stages of the development of the new mechanism for maintaining a biologically adequate relation of the animal to the atmosphere. The diaphragm makes its appearance here, and I am one of those who dissent from the view that the diaphragm is of relatively little importance in respiration. All mammals may continue to take food or hold prey with the teeth without being compelled to stop occasionally to swallow air.

The change from the respiratory mechanism of fishes to that of the first air-breathing animals which can range far from the water for long periods of time, and to the further stages attained in mammals has involved far more than the mere development of lungs. A new motor mechanism, with a highly organized and extremely efficient mechanism of nervous control, has been quite as necessary as the lungs themselves. The muscular changes have been considerable, but the changes in the nervous system have been quite as profound as those in the motor mechanism. But this nervous mechanism, in common with other highly organized machinery, has little possibility of new attainments (Hughlings Jackson) or of learning very much. Truly, the difficulties encountered in the transition from an aquatic to a terrestrial habitat have been great, and the first group to leave the water—the amphibians—has not wholly succeeded in overcoming them.[3]

The new mechanism, as far as I can see at present, first begins to assume a settled and definite form in reptiles. It is my present view, although the experimental evidence is not yet complete, that the respiratory connections with the midbrain, while partly established in amphibians, are first adequately established in reptiles. This seems only one more fact pointing to the importance of the reptilian group for the comparative physiologist who wishes to approach the study of the problems of organic evolution from the point of view of experimental physiology.

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A NEW FORMULA FOR THE ELECTRICAL RESISTANCE OF CERTAIN INHOMOGENEOUS SYSTEMS

IN the February number of the *Journal of Infectious Diseases* there is a paper by Dr. R. G. Green and myself dealing with the electrical conductance of systems of the following type: a suspension of yeast cells in a salt solution. In that paper we gave an approximate expression for the resistance of the suspension in terms of the volume occupied by the suspended particles and the specific resistances of the menstruum and of the suspended materials. I have recently arrived at a relation which I believe to be much more accurate.

Let c be the constant of the cell in which the resistances are measured; s, the specific resistance of the suspended material; a, the fraction of the total volume occupied by the suspended cells (assumed to be spherical); R, the resistance of the suspension; and M, the resistance when the salt solution alone fills the apparatus. Let $S = cs$.

Then the new equation is

$$R = M \left\{ \frac{1 + a \left\{ \frac{S - M}{2S + M} \right\}}{1 - 2a \left\{ \frac{S - M}{2S + M} \right\}} \right\} \text{ or}$$

$$a = \frac{(R - M)\,(2S + M)}{(2R + M)\,(S - M)}$$

For the case in which the suspended particles have an infinite resistivity,

$$R = M \left\{ \frac{1 + \frac{a}{2}}{1 - a} \right\} \quad \text{and } a = \frac{2(R - M)}{2R + M}$$

Dr. Green and I will submit for publication in the near future a paper in which we shall undertake to prove the correctness of the formulae given above, and in which we shall apply them to experimental data old and new.

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THE AMERICAN PHILOSOPHICAL SOCIETY

THE American Philosophical Society held its annual meeting in Philadelphia on April 24, 25 and 26, with the following program:

THURSDAY, APRIL 25

The fate of the soul of the elect in Manichaeism: A. V. WILLIAMS JACKSON, professor of Indo-Iranian Languages, Columbia University.

The Bornholm dialect of Danish: JOHN DYNELEY PRINCE, envoy extraordinary and minister plenipotentiary to Denmark.

Balder and the Golden Age: HERMANN COLLITZ, professor of Germanic philology, Johns Hopkins University.

Some effects of baths on man: H. C. BAZETT, B.Ch. (Oxon.), professor of physiology, University of Pennsylvania.

Differential permeability and cell reaction: M. H. JACOBS, Ph.D., professor of general physiology, University of Pennsylvania.

Pneumonia in Pittsburgh: EWALD TOMANEK, M.D., and EDWIN B. WILSON, Harvard School of Public Health.

The amending provision of the Federal Constitution in practice: HERMAN V. AMES, professor of history, University of Pennsylvania.

On the authorship of the anonymous pamphlet published in London, in 1760, entitled "The interest of Great Britain considered with regard to her colonies": I. MINIS HAYS, of Philadelphia.

The nation's transportation problem: EMORY R. JOHNSON, professor of transportation, University of Pennsylvania.

[3] I am indebted to Dr. G. K. Noble for much information on the various adaptations and shifts which these forms have tried in the first attempt at terrestrial life. I would appreciate data bearing on peculiar means of respiration in other forms.