Kiær looks upon the spines of the Anaspida and the lateral lobes of the Cephalaspidae as homologous with paired fins and as originating in lateral fin folds. The absence of any homologue of the pelvic appendages is believed to be primitive.

As regards the affinities of the group the following views are advanced:

(1) He concurs in the "general view" that the Acrania, Cyclostomata and Pisces form three ascending stages in the development of the Chordata (although, to be sure, the Acrania and Cyclostomata as we know them are specialized and to some degree degenerate).

(2) The dermal skeleton was characteristic of a normal stage in this development. The earliest forms were naked, then arose a scale system governed largely by the mechanics of the lateral muscle plates, and passing by later development into various specializations, such as fusion into plates, as in the ostracoderms, or on the other hand reduction or loss.

(3) The unpaired nasal opening and pineal organ, their grouping with the eyes and the structure of the branchial apparatus are believed to be the most important structures of the Anaspida. Now in all these characters they resemble the cyclostomes (Petromyzontia) and furthermore these are just the characters which separate the latter from the true fishes. The unpaired nasal opening is considered especially fundamental and Haeckel's grouping of all vertebrates into Monorhina and Diplorhina is revived. Hence the Anaspida are believed to belong to the same group of monorhine craniates as the cyclostomes. The absence of a dermal skeleton, jaw structures and paired pectoral appendages in the latter are considered secondary due to degeneration.

(4) As to the other groups usually united under the designation Ostracodermata, the Cephalaspidae are close relatives of the Anaspida. Pteraspidae and kindred forms (Heterostraci) are, however, very different, and it is considered probable that they are related to the Elasmobranchii, as Traquair believed. As for the Antiarchi, these forms are so isolated as to be altogether uncertain in position. They can scarcely be assigned any close connection with the Arthrodira and are in any event diplorhine and true fishes.

An outline of the classification which concludes the work may be given here:

Subphylum Vertebrata Craniata.
Branch I. Monorhina.
Class I. Anaspida:
Lasaniidae,
Birkeniidae,
Pharyngolepidae,
Pterolepidae,
Rhyncholepidae,
Euphaneropidae.
Class II. Cephalaspidomorphi.
Class III. Cyclostomata.

The fourteen plates are reproductions of photographs and bear abundant witness to the wonderful preservation of the material.

The theoretical conclusions of this monograph will undoubtedly give rise to much discussion and some differences of opinion. There is, however, no room for discussion as to the painstaking and accurate nature of the work nor as to its meriting the high praise and wide notice which it will undoubtedly receive. The gaining of a thorough knowledge of these members of the Anaspida, a group so ancient and so fundamental as to be of the highest interest for any student of vertebrates living or extinct, is an event of the very first magnitude.

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## SCIENTIFIC APPARATUS AND LABORATORY METHODS

### REACTION OF OPALINAS TO VARIOUS LABORATORY MEDIA

PHYSIOLOGICAL salt solution has for many years been the traditional and all but universal medium in use for maintaining organisms and tissues in biological laboratories.

In a series of experiments on *Opalina obtrigonoidea*, begun for another purpose, we have however found, rather contrary to our expectations, that physiological salt solution is not as efficient as several other common laboratory media for keeping Opalinas alive. By the use of Locke's solution, 50 per cent. sea-water, etc., Opalinas may be kept alive for a considerable length of time outside of their natural habitat in the cloaca of the leopard frog (Rana pipiens). It has been observed in a number of other instances that sea-water of various concentrations is an excellent medium; this has also proven true in our work on Opalinas. In our experiments it has been observed to be almost on a par with Locke's solution, which we found to be the best of all the solutions we used.

Eight different media were tried with varying results as shown in the table below.

These results we hope will be of interest to teachers of biology who wish to demonstrate or study such parasitic protozoa as are found in frogs. All the protozoa that one may desire may be obtained from frogs used for other class purposes. This may easily be done by removing the cloaca from a freshly killed

LENGTH OF LIFE OF OPALINAS IN VARIOUS LABORATORY MEDIA

| | In clear fluid | With cloacal content | With piece of cloaca |
|---|---|---|---|
| Locke's solution | 28 hrs. | 35 hrs. | 73 hrs. |
| Sea-water, 50 per cent. | 22 " | 25 " | 45 " |
| Pond water | 25 " | 34 " | 36 " |
| Ringer's solution | 32 " | 26 " | 35 " |
| Physiological salt solution | 21 " | 25 " | 25 " |
| Tap water | 13 " | 13 " | 13 " |
| Distilled water | 9 " | 9 " | 9 " |
| Kroniker's solution | 4 " | 4 " | 4 " |

frog and opening it in a watch glass half filled with the desired medium. The most satisfactory results are obtained by dividing the material among two or three dishes so that each dish has a piece of the cloaca and a part of the cloacal content. The watch glasses should be kept covered to prevent too great evaporation and consequently too great concentration of the salts. The Opalinas in such a solution may be expected to remain alive and in good condition for two days or more and in the case of *Nyctotherus* for as long as six days.

The above solutions are easily made up and sea-water may be readily obtained at any biological supply station or be made synthetically according to Mayer.[1]

A more complete report on the longevity of *Opalina obtrigonidea* in various media together with other observations is in preparation for publication later.

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## SPECIAL ARTICLES

### SURFACE TENSION DETERMINED BY THE RING METHOD

IN recent years a considerable amount of attention has been given to the problem of finding a method by means of which the surface tension of a liquid can be measured rapidly and with some degree of accuracy. An apparatus in which the pull on a ring is measured by means of the torsion of a wire evidently meets the requirements of convenience and rapidity. Such an apparatus has been devised by du Noüy.[1]

According to the simple form of the theory underlying the use of the ring method, the surface tension of the liquid is equal to the pull on the ring at the instant of rupture of the films of liquid divided by twice the circumference of the ring. Unfortunately the values obtained in this way are certainly too high. Paul E. Klopsteg[2] has attempted to explain the high values obtained by the method of the torsion-balance on the ground that as the ring is lifted out of the liquid the zero of torsion no longer corresponds to the zero of the scale. He suggests that as the torsion on the wire is being increased the vessel containing the liquid must be lowered so that the arm will at all times be in its position of zero-balance. This procedure is undoubtedly correct. But I do not think that the simple theory of the experiment even with the procedure advocated by Klopsteg can lead to accurate values of the surface tension.

It is well known that, after the ring has been detached from the liquid, droplets frequently adhere to it. Klopsteg suggests that a correction must be applied by adjusting the zero-balance of the instrument with the droplets adhering to the ring. I hope to show that the magnitude of the pull on the ring is independent of whether droplets are formed on the ring or not.

In this discussion I shall use the following symbols:

$R$ = average radius of ring.
$r$ = radius of circular cross-section of wire used in making ring.
$p$ = total pull on ring in dynes divided by $4\pi R$.
$\alpha$ = surface tension in dynes per centimeter.
$s, g$ = density of liquid and acceleration of gravity respectively.
$a^2$ = specific cohesion $= \frac{2\alpha}{sg}$
$\alpha = p$ (on the basis of the simple theory).

During the last two or three years, Dr. R. G. Green, of the department of bacteriology, has been carrying out measurements with platinum rings having values of $r$ from .015 to .05 cm and of $R$ from 0.3 to 1.3 cm. We soon found that the value of $p$ is a function of $r$ and $R$, increasing rapidly with increase in $r$ and diminishing slightly with increase in $R$. We also observed that a maximum pull is reached before the film breaks. If there is in fact a maximum pull, it is evident that its magnitude will be independent of such phenomena as the actual breaking of the film and the adherence of droplets of liquid to the ring.

At this stage in our studies, I came across an ar-

[1] "The relation between degree of concentration of the electrolytes of sea-water and rate of nerve-conduction in *Cassiopea*," by A. G. Mayer, from Papers from the Tortugas Laboratory of the Carnegie Inst. of Wash., Vol. VI, 1914. Publication No. 183.

[1] *Journal of Gen. Physiology*, I, 521–524 (1918–19).
[2] SCIENCE, October 3, 1924.