at sea, that it should be driven at a constant speed, and a special tuning-fork controlled rotary converter, situated in the after part of the vessel and driving through an articulated phosphor-bronze shaft, will be provided to ensure this. Two galvanometers, one of the moving coil type, with short period, and the other of the string type will be provided and experience will be gained at sea of the relative suitabilities of the two types. The earth-inductor will be mounted in an after observatory.

Portable instruments for land observations, at fixed magnetic observatories and elsewhere, will also be carried. The designs of the instruments have been based on the Carnegie Institution designs, with such modifications as were suggested by experience on the *Carnegie* or as seemed desirable for various reasons.

The magnetic observations on the R.R.S. *Research* will be made primarily in the interests of navigation. But they will provide at the same time valuable information about the earth's magnetism, which is needed for the investigation of such matters as the non-potential portion of the earth's field and the line integrals around closed contours on the earth's surface.

Body Orientation of the Lower Crustacea (Branchiopoda)

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AMONG the Branchiopoda it is now well known that the Anostraca swim normally lying on the back, while the Notostraca swim with the back directed upwards. Orientation is also constant among the Cladocera, but there are here considerable differences between genera.

Four possible controlling factors have been suggested. These are the aeration of the water, gravity, the surface resistance of the animal, and light.

Lowndes[1] and Wertheim[2] hold that the limbs of Anostraca, which are doubtless respiratory, are normally directed upwards because the upper layers of water are best aerated. This view, however, cannot apply to the Notostraca. Nor could orientation be controlled in this way except perhaps very near the water surface, since the differences in aeration above and below a swimming animal must normally be too small to be detected. It is true, however, that both Anostraca and Notostraca often come up and beat their limbs just below the surface film, the Notostraca specially turning over on to their backs for this purpose. It has been widely stated that this occurs especially when the oxygen content of the water is low. It may thus well be a respiratory phenomenon, though Mathias[3] has shown that the oxygen requirements of *Artemia* are surprisingly small. In any event, however, the habit is quite distinct from the more usual swimming of the animals farther below the surface.

Control of orientation by gravity may occur in two ways. There may be automatic control, the centre of gravity of the animal being so placed that a constant attitude tends to be maintained independent of muscular effort. The factor of the resistance offered by the surface shape of the animal to the water may also play a part here. Or there may be nervous control due to the effect of gravity on special sense receptors, the position maintained by the animal being then not necessarily the stable one with respect to the automatic forces just mentioned.

Surface resistance is a factor of special importance in the Cladocera, because of the regular rest pauses which characterize their swimming. But in the Anostraca and Notostraca, considered for the sake of simplicity only when swimming or floating more or less horizontally, the effect of surface resistance on dorso-ventral orientation must be small. R. T. Muller[4], however, has shown that for Anostraca the effect due to the centre of gravity may be important. It has long been known that in water the anostracan body sinks back downwards. This might be due to the position of the centre of gravity, or to surface resistance. Müller showed that it is due to both these factors. He placed both fixed and narcotized *Tanymastix* in sugar solution of the same specific gravity as that of the animals, and found that they then lay floating in the solution back downwards. This could be due only to the position of the centre of gravity. He then raised the specific gravity of the solution until the animals rose up fairly rapidly towards the surface; they did so back upwards, surface resistance overcoming the force exerted by the centre of gravity. Thus when an anostracan sinks in water, both forces tend to keep the back downwards. For the Notostraca, such careful experiments have not been done; but Seifert[5] has shown that a dead *Apus* also sinks in water back downwards. Probably this is due to the same forces acting together as in the Anostraca. If this is so, then *Apus* normally swims in an unstable position with respect to its centre of gravity, and if gravity plays any role in controlling orientation it must be by acting on sense receptors. But although *Apus* has been histologically well investigated, nothing in the nature of a statocyst has been found.

The effect of light on the dorso-ventral orientation of Anostraca and Notostraca may be very marked. But Müller[4] gives much experimental evidence to show that in the anostracan, *Tanymastix*, the responses occur only when phototropism has been awakened by other stimuli; the possibility that this may also be the case for the Notostraca has not been investigated. Both orders, however, respond to sudden changes in the direction of light, the Anostraca seeming always to try to keep the ventral surface facing the source of light, while Notostraca show the opposite response. This corresponds with the normal swimming positions of these animals when light is coming from above. When illuminated from below the animals turn over, though the fresh-water Anostraca seem to find difficulty in swimming in the unaccustomed and unstable position. Individuals of *Streptocephalus* observed by me repeatedly 'looped the loop' when illuminated from below, swimming slowly ventral side down when at the bottom of the loop and going rapidly, ventral side up, over the top of the loop. *Apus* when illuminated from below swims easily on the back, this being for it, as it is for the Anostraca, the presumably stable position with respect to the centre of gravity. In both Anostraca and Notostraca, control of orientation in respect to light has been shown by Seifert to be effected in the first place solely through the eyes. In the Anostraca he has shown[6] that probably only the lateral eyes are concerned. In the Notostraca he has found[5] the lateral eyes to play the chief part, assisted, however, to a small extent by the median eye.

It may be concluded that, while in fresh-water Anostraca control of orientation by light is probably secondary to that exerted by the centre of gravity, this is apparently not so for the Notostraca. Here the normal swimming position is perhaps in direct response to the direction of light, although the possibility that gravity plays a role is not excluded. Seifert[5] found that *Apus*, in response to a change in the lighting, appeared to turn over more rapidly to the normal position with the back upwards than it did for the reverse change. He also found that when the normal habitat conditions are reversed, by lighting from below and placing a false bottom above, *Apus* does not behave towards this false bottom in the same way that it does towards a true one when the light comes from above. But the tendency for the animal to sink rather spoils the significance of this experiment. Much more interesting should be the behaviour of the animals at night. I have found, in agreement with Müller, that fresh-water Anostraca continue to swim ventral side up at night, this being the stable position with respect to the centre of gravity. But for the Notostraca I have no observations on this point, and I can find only two brief notes by Seifert[5]. He states (p. 403) that animals swimming in the dark show some uncertainty in their orientation, and (p. 414) when allowing themselves to sink down after a period of swimming, do so back downwards. These observations, if they are correct, would seem to show that it is indeed light which controls the normal daytime swimming position of the Notostraca. In fresh-water Anostraca this control is probably more latent, being awakened, according to Müller, only by certain disturbing stimuli.

An interesting confirmation of the probable truth of these general conclusions is contained in the later paper by Seifert[6]. In this paper, Seifert compares a fresh-water anostracan, *Chirocephalus*, with the 'brine-shrimp', *Artemia*. For *Chirocephalus* his results are in close agreement with those of Müller on *Tanymastix*. But he finds that in *Artemia* conditions have been reversed by the nature of the environment. *Artemia* swims on the back like other Anostraca, but Seifert finds that in the strong brine in which it lives, this is actually the unstable position, because its body is tending to rise rather than to sink. Correlated with this presumed instability of the normal swimming position, there is a much more constant orientation of the body with respect to light than has been found in other Anostraca. Probably Seifert would thus divide the Euphyllopoda into those forms which normally swim in a 'stable' position and respond to light only after suitable stimulation, and those forms which swim in an 'unstable' position, maintaining their orientation by a constant response to the direction of light.

Clearly other factors than light and gravity, such for example as the currents set up by the animal, may also play a part. But for the sake of simplicity I have not considered these here; nor have I more than briefly mentioned the Cladocera, because the large amount of work done on this group has already been well reviewed (*cf.* Wagler[7]).

[1] A. G. Lowndes, *Proc. Zool. Soc. Lond.*, p. 1093 (1933).
[2] P. Wertheim, *Zool. Anz.*, **108** (1934).
[3] P. Mathias, *Ann. Sci. nat. Zool.*, (x), **17** (1934).
[4] R. T. Müller, *Z. Biol.*, **69** (1919).
[5] R. Seifert, *Z. vergl. Physiol.*, **11** (1930).
[6] R. Seifert, *Z. vergl. Physiol.*, **16** (1932).
[7] E. Wagler, Branchiopoda, in Kükenthal and Krumbach, "Handbuch der Zoologie" Bd. 3, H.I. (1926–27).