just as an oak is a perfectly definite type of a tree. Taking $q=x+yi+zj+wk$ as the type of a quaternion, we may generalise the "scalars" x, y, z, w, by making them ordinary complex numbers, or elements of some other algebra, commutative with i, j, k, and combining according to laws of their own. We thus embed the quaternion algebra, so to speak, in a larger composite algebra; but it is most undesirable to call this an extension, still less a completion, of quaternions.

The reader should be warned that the author often says "must" when there is no logical necessity at all. For instance, we are told that, β having one dimension in length, β^2 "must" have two; yet on the next page we are told that $\alpha\beta\gamma\delta$ means a solid angle, thus apparently having no dimensions in length, at any rate not four. This kind of fogginess is very common, even among quaternionists. Thus $ij=k$, so the product of two vectors can be a vector, and the law of dimensions is violated, or rather does not apply. Of course, in physics, it is convenient to represent areas, moments, &c., by vectors, and then the quaternion formulæ become more significant. We might, if we liked, put $ij=k_2$, $jk=i_2$, $ki=j_2$, regarding i_2, j_2, k_2 as areal units, and then have what Grassmann would call a regressive multiplication, $i_2j_2=k$, $j_2k_2=i$, $k_2i_2=j$, bringing us back to one dimension again. But anyone can see that this is unnecessary complication; in all physical applications of quaternions it is easy to see whether a vector is to be interpreted literally, or as the representative of some areal quantity.

Whatever may be the ultimate fate of this particular algebra, Dr. Macfarlane's researches deserve recognition. He has the spirit and the courage of a heretic, and every honest heretic helps to advance the truth.

G. B. M.

UNITED STATES METEOROLOGICAL PUBLICATIONS.[1]

(1) THE first thirty pages of the report of the Chief of the Weather Bureau for the year 1911–12 contain a summary of the work accomplished by that department during the year. This is followed by a general statement of the weather conditions prevailing in the individual months, while the last and by far the longest part of the report is devoted to tabulated statistics of the different meteorological elements with summaries of sunshine, excessive rainfall, &c.

An account of the work done at the upper-air station on Mount Weather is given first place in the volume, and from this we learn that it is proposed to modify the plan hitherto followed of attempting to obtain a kite or balloon flight on each day, regardless of the weather conditions, and to substitute a series of special ascents made to investigate particular problems. It is interesting to learn that a special department is being inaugurated at this observatory for the training of observers for duty at the 200 out-stations of the weather service. At the central office a synoptic weather chart is prepared each day for the whole of the northern hemisphere, and on this map are based general forecasts of the weather and temperature conditions over the United States for a week in advance. It is intended shortly to institute a service of wireless reports from ships in the Atlantic, and to transmit information as to the location and movements of dangerous storms to vessels from one of the high-power stations on the coast. Extensive observations are now being made on the snowfall of the western mountain ranges, and it is hoped to be able in the future to give useful forecasts of the flow of those rivers which are fed in the spring and summer by the thawing snow. A feature of the report is the list of new books added to the library during the year. Many of the more important of these works are referred to individually, and a short account is given of the scope covered by each book. This should prove useful for purposes of reference. It is evident from a perusal of the volume that the operations of the bureau are conducted on a very large scale, as befits an institution dealing with meteorological information from an area like that of the United States.

(2) The impending opening of the Panama Canal renders the subject of the second paper of especial importance at the present time. In addition to dealing with the West Indian hurricanes, the author sets out comparative data for the typhoons of the Pacific and the cyclones of the Bay of Bengal. All these disturbances are of the same type, characterised by a moderate decrease of atmospheric pressure to within forty or fifty miles of the centre, and then the rapid fall associated with the destructive winds which cause such havoc in the belt passed over by the central region of the disturbance. Nearly all the West Indian hurricanes have their origin in a well-marked area bounded by the parallels of 12° and 26° N. latitude, and lying between 56° and 90° W. longitude. The typical track is parabolic in shape, the storm moving W.N.W. at first, then curving round to the N., and finally passing in a north-easterly direction to the North Atlantic. The average rate of travel of these storms is only 300 miles per day, so that the forecaster is often enabled to give a fairly long warning of their approach. Much useful information is contained in the paper, and Dr. Fassig is to be congratulated on the completion of a trustworthy piece of work.

J. S. D.

[1] (1) Report of the Chief of the Weather Bureau, 1911–12.
(2) Hurricanes of the West Indies, Dr. O. L. Fassig.

REFLECTION AS A CONCEALING AND REVEALING FACTOR IN AQUATIC AND SUBAQUATIC LIFE.[1]

AS a result of observations and experiments carried out on ponds built for the purpose, and by the use of apparatus for observing organisms in their natural environments, I have arrived at certain conclusions as to the value of reflection as a concealing factor in various forms of aquatic and subaquatic life. The general principle upon which these ponds are built is as follows:—In one bank of the pond is a glass window, and beyond this window an underground observation chamber. No light enters this chamber except through the surface of the water. By this means everything in the pond is seen by *entirely* natural illumination, the observer cannot be detected, and as there is no reflection from the glass the making of photographic records is greatly simplified. In the first pond, built for the observation of objects in the water, the glass is perpendicular. In the second, for observing objects on the surface, the glass is at an angle of 45° to the surface.

Of apparatus I use a tube 18 in. square and 5 ft. long. On one side at the lower end is a window; into this tube slides a reflex camera, so that the lens is opposite the glass. When in use, a heavy weight carrying a hook is lowered into the water, with the end of the tube attached to the hook. The whole apparatus can be tilted at any angle, and by this means the incident rays from any object in any position—except overhead—are made to strike the glass at right angles, and thus distortion, due to refraction through the glass, is rendered negligible.

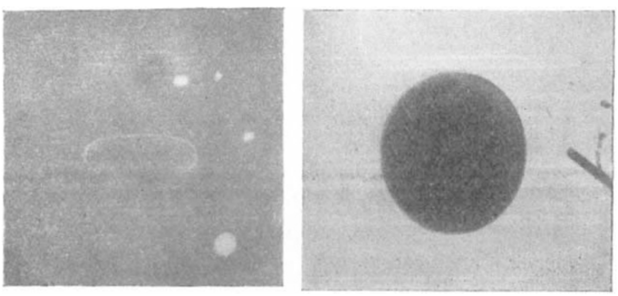
[1] Discourse delivered at the Royal Institution on Friday, June 6, by Dr. Francis Ward.

The apparatus has been mainly used as a check upon observations in the ponds.

For observing and photographing life on the bottom, I use a tube 3 ft. long, with a glass partition inside, a foot from the end. This apparatus acts as a boat-like sea telescope, and is fitted with a camera. Lastly, through the kindness of Prof. Herdman, I have established at Port Erin a large wooden tank above ground. Three sides of the tank incline at an angle of 45°; the fourth is perpendicular. In the perpendicular side is a glass window, and attached to it an observation box, 6 ft. by 4 ft. The tank and observation box revolve together on a platform; by this means an object in the tank can be seen by reflected and transmitted light at will.

It is usual to consider pigmentation as the main factor in the concealment of subaqnatic life. Among organisms that live in more or less the same character of surroundings, pigmentation is undoubtedly most important; but in the forms of life that are constantly changing their environments, the best concealed are those that most effectively reflect their surroundings.

When, however, an organism depends mainly upon reflection for its concealment, the reflection of light from above has to be modified, or else the organism is revealed. In some forms of life, particularly fishes, pigmentation upon the back is the method of modifying this reflection from above. In other forms this top light is cut off by position, *e.g.* in light-coloured anemones, which are only to be found attached to the under-surface of shelving rocks.



White saucer on the surface in the area of total reflection. White saucer on the surface in the circle of light.

FIG. 1.

Before proceeding further, I would like to illustrate the appearance of a white object, as seen from under the water. I show a sheet of white cardboard pinned on a red stick, which in turn was stuck in the centre of an *empty* pond. The sides and bottom of the pond were covered with green confervæ. In this position the card appeared white, and incidentally the stick red.

The pond was then filled up with water, and now the white card so exactly reflected the colour around that it became practically invisible, yet its position was revealed by a streak of light along the upper edge of the card.

In nature all white subaquatic organisms reflect in a similar manner, and white is never seen under the water, except when there is no provision made for modifying the reflection of light from above, or when the organism turns on its side.

As an illustration of this point, let us consider the white anemone (*Actinoloba dianthus*). I show a colour-plate of this anemone attached to the top of a rock and, of course, it appears white, but as soon as it moved only a distance of 2 in. under the shelving edge of the rock, the top light was cut off, and you will see the white anemone appears green as it reflected the prevailing colour below.

It will be noticed that the white serpula on the rock reflects in the same manner; and as the light parts of rock also appear of a greenish colour the anemone and the serpula are practically invisible. Advisedly I say practically invisible, for the greenish anemone when closed makes a uniformly shaded green mass against a patterned rock.

It will have been noticed that the red stick holding the white card, when seen from under the water in green surroundings, appeared a dull black.

When *Tealia crassicornis* (a red and white anemone) is attached to the under-surface of a rock with a green coloration below, the whites of this anemone appear green and the red markings appear dark, so that now the anemone shows a general green coloration with dark markings upon it, which fit in with the dark markings on the stone. Many forms of light-coloured marine life are found under shelving rocks. I consider they escape destruction in this position owing to the fact that they reflect their surroundings.

Next let us consider the modification of reflection by pigmentation. This is best illustrated in fishes. Until one has observed fish by *entirely* natural illumination, it is difficult to realise how important a part reflection plays in rendering both silvery and highly pigmented fishes inconspicuous.

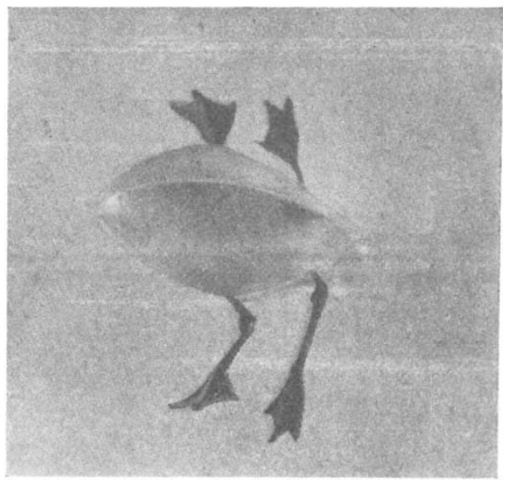


FIG. 2.—Lesser black-backed gull on surface in area of total reflection. (From life.)

The silvery fish does not appear silvery, but red, brown, or green, according to the general colour around, and in addition it will reflect upon its body stem for stem the reeds into which it has rushed in order to hide itself.

As an illustration to show how a highly pigmented fish reflects light, I show a tench, only 6 in. under the water, and it will be seen the dark back appears quite silvery.

Pigmentation on the back conceals a fish against the bottom, but undoubtedly the important function is to conceal it, for protective and aggressive purposes, from other fish on the same level as itself. I would point out that the same light which is reflected from the sides of the fish, through the eye of the fish, controls the amount of contraction of the pigment cells on the back: thus the reflection from above is correctly modified, and the fish is rendered a uniform shade. But this uniform shade only conceals against a uniform background.

Thayer has shown in the animal world how the counter-shaded bird, or beast, without markings, when seen against a patterned background, becomes conspicuous, because it interrupts the pattern. The same is seen in the fish world, and in illustration I would direct your attention to the appearance of a perch (*Perca fluviatilis*) swimming past a reed bed.

In the autochrome of a brown trout lying under a stepping-stone, I show the value of reflection; here, the back green, and the belly red, as they reflect the stones above and below, are undoubtedly the main factors in concealing this fish, and the markings simply prevent the body from appearing patternless.

I would next direct your attention to the possible influence of reflection of light, from some forms of marine vegetation, upon the pigmentation of various marine organisms. Several red and brown seaweeds seen by transmitted light appear red and brown, but when seen against a dark background they reflect at various points a brilliant bluish-purple colour. Chondrus shows this well. In certain positions the whole side of a dark rock, covered with red and brown seaweed, shows blotches and streaks of bluish-purple. This is well marked upon the concrete blocks on the old breakwater at Port Erin.

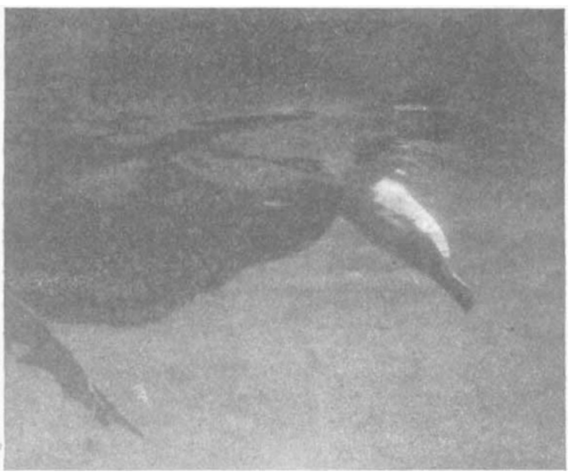


FIG. 3.—Cormorant on surface dipping head under water. (From life.)

Lobsters, crabs, and many other forms of marine life, usually found in crevices among dark rocks covered with red and brown seaweeds, show a pigmentation exactly similar in appearance to the colour reflected from the seaweed. This is particularly well marked in the swimming crab, *Portunus puber*.

I would now refer to the appearance of life on the surface, as seen from below. This appearance entirely depends upon the position that the particular organism occupies on the surface, relatively to the point of observation from below the water.

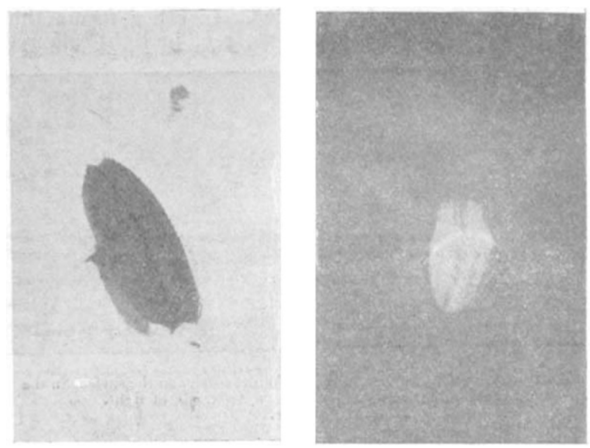
On looking up to the surface, an observer sees above him a circle of light, through which he can see the sky and clouds. Beyond this circle there is total reflection, and the surface of the water reflects the general colour below. Transparent organisms are practically invisible, both in the circle of light and beyond. Now it is generally understood that forms of life that occasionally or habitually float on the surface are white underneath, so as to conceal them against the clouds and wave foam.

In dealing with this subject it is necessary to make a difference between white organisms that are opaque and those that are translucent. Commencing with the opaque, I will illustrate the point with the appearance of a thick white saucer. This was floated from some distance over my head. Outside the circle of light the surface of the water was reflecting the green bottom of the pond, the white saucer did the same, and, therefore, was invisible against the surface of the water. When, however, it came into the circle of light it still reflected the dark colour below and was revealed as a well-defined dark object against the sky and clouds.

A white-breasted gull swimming on the surface is concealed and revealed in an exactly similar manner. Therefore, an opaque white organism in the circle of light is not concealed, and when seen against the clouds the whiter the object the more conspicuous it becomes, because it reflects the dark water below. A white object is, however, concealed by reflection in the area of total reflection.

How does this explanation affect the concealment of an opaque white object on the sea from a fish? The size of the circle of light on the surface depends entirely upon how far the fish is under the water, for lines drawn from the two ends of the diameter of the circle make an angle of 97° at the eye of the fish.

When the fish is some depth under the water there may be several white seagulls on the surface within



Shell of argonauta on the surface in circle of light. Shell of argonauta on the surface in area of total reflection.

FIG. 4.

the circle of light, but as the fish comes up to feed his circle of light is narrowed down, and the gulls slip into the area of total reflection and by reflection become invisible to the fish.

For my experiments with translucent organisms I used the shell of an argonauta. In the circle of light you will see the shell is still very obvious, but as it transmitted a considerable amount of light it did not appear black like the white saucer. In the area of total reflection, however, the shell appears white, for in consequence of not being an opaque object it is no longer a reflector.

Argonauta seems to slip between two stools; it is too opaque to be concealed in the circle of light, and too translucent to be concealed in the area of total reflection. In the latter situation it certainly may be protected by simulating the appearance of wave foam, for wave foam in the area of total reflection appears as a flickering light.

So far we have only considered that portion of an object that is actually immersed. If, however, the organism under consideration is not too far distant, that portion of it above the water is visible on the edge of the circle of light, and the parts respectively above and below appear to be separated by a considerable interval of water surface. When the portion above the water is white, as in a gull, it is difficult to detect against the sky. The above remarks only refer to open water, and I will illustrate how a wading bird is concealed against the image of a reed-bed many yards behind him. Looked at from below the markings on a heron are in bold upright lines, for the plumage is greyish-white with black patches on each side of the head, and the black patches on the shoulders appear continuous with the black primaries of the wings. Seen against an open sky, the white parts of the wading heron blend with the sky, but the black parts stand up in bold relief. The head and shoulders of the bird are seen on the edge of the circle of light, but so also is the reed-bed many yards behind. The reeds, seen as perpendicular images, and the perpendicular markings on the heron blend, and thus make the bird inconspicuous.

I have referred to white as a concealing agency. Black objects, when they retain air-bubbles on their surface, also become reflectors under the water. The black water-spider under a leaf appears green and is lost to sight. A waterhen swimming on the surface in the area of total reflection reflects the green weeds below, and becomes difficult to discern against the surface which is reflecting the same colour.

In conclusion, I will refer to reflection as a revealing factor. I have already illustrated this point with the anemone. I now show a slide of a shoal of young rudd wheeling round, and as they turn each fish is revealed as a flash of light as he catches the light from above.

Among diving birds the cormorant does not retain air bubbles in his feathers to the same extent as the loose-plumaged waterhen, yet by reflection he appears light or dark, according to the nature of the bottom over which he is swimming. When, however, the cormorant dives his track is marked by a series of brilliant flashes of light.

Now this bird when swimming on the surface has the habit of dropping his head under water at regular intervals—shags do the same. Seen from below, every time he does this, there is a flash of light not unlike the flash from a silvery fish turning. It is quite possible that fish, such as pollock and codling, are attracted by this flash, and thus swim towards their destroyer. These flashes of light are still better shown in the case of the penguin, and this I illustrate with individual pictures cut out of a kinematograph film.

I have had to leave the subject of refraction of light on the present occasion; first, because time does not permit of my dealing with it, and, secondly, because during the last fortnight I have tested all my experiments at Port Erin, and some of the results have made me reconsider the conclusions at which I had arrived with regard to the refraction of light in its relation to marine organisms.

1 3

2 4

1. Stuffed heron with neck straight out prepared to strike a fish.
2. Appearance of heron under the water. (From life.)
3. The same bird as he appears on the edge of the circle of light against the sky. Notice how the tree 160 ft. away and the body of the bird appear to be one.
4. Reeds were then placed 5 ft. behind the bird, and now his head and neck are not easy to detect.

When the above photographs were taken the lens of the camera was a foot below the water-level, and the heron was 4 ft. distant.

FIG. 5.

TECHNICAL EDUCATION FOR INDIAN STUDENTS.

THE report of a Committee appointed by the Secretary of State for India to inquire into the system of State technical scholarships established by the Government of India in 1904, has been published as a Blue-book (Cd. 6867). On March 27, 1912, the Secretary of State appointed a Committee "to inquire and report as to the facilities available for Indian students for industrial and technological training in this country, with special reference to the system of State technical scholarships established by the Government of India in 1904." The Committee was constituted as follows:—Sir Theodore Morison, K.C.I.E. (chairman), Sir K. G. Gupta, K.C.S.I., Mr. J. H. Reynolds, Prof. W. E. Dalby, Mr. P. H. Dumbell (secretary), Mr. R. E. Field (assistant secretary). The Committee held its first meeting at the India Office on May 9, 1912, for the purpose of discussing the itinerary, and considering questions of procedure. On various occasions the Committee visited Glasgow, Leeds, Manchester, and Birmingham, where they received evidence from the higher education authorities, and visited the various laboratories, and so on, devoted to technical education. Altogether during the provincial meetings the Committee took evidence from seventy-five witnesses, of whom twenty-nine were professors and