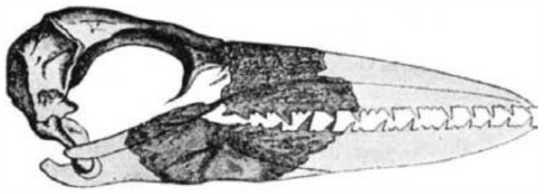
TEETH AND THEIR SUBSTITUTES.*

NATURE'S FOOD CRUSHERS.

BY W. P. PYCRAFT.

THOUGH Nature evidently meant the vertebrates to be a tooth-bearing race, this design has been by no means rigidly adhered to, as many creatures of very different orders have been permitted, so to speak, to adopt various substitutes therefore.

The earliest tooth bearers among the limb-bearing vertebrates are to be found among the shark tribe—using this term in a wide sense—and it is here that we must look for the origin of teeth, searching, if not "with forks and hope," after the fashion prescribed for shark hunting, at any rate with scalpel and microscope.

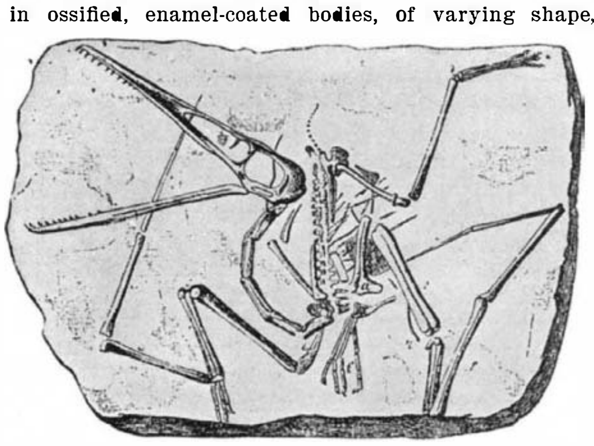


Skull and lower jaw of Odontopteryx toliapica, with bony denticles on jaws, from the London Clay of Sheppey. (2/3 nat. size.)

Properly conducted such a search reveals the truly astonishing fact that the earliest, most primitive forms of teeth are really nothing more than modified scales. In the sharks, it may be remembered, as in the common dog-fish for example, the surface of the skin is incased in a mosaic of tiny, closely fitting ossicles, bearing each an enamel-covered spine, and skin so covered was at one time in great request for commercial purposes, being known as shagreen. In the embryo dog-fish it will be found that the skin covering the jaws is perfectly continuous with that of the body and is similarly incased. Later, however, the scales in this region become enlarged and assume the characteristic form of teeth. Among the sharks this dentition has become modified in many ways, the most striking of all being the evolution of "pavement teeth"—broad, flat plates, symmetrically disposed, and used for crushing purposes.

But we are not concerned here with the various forms of teeth, so much as the substitutes therefor, which, for one cause or another, have been adopted by different groups of vertebrates. Suffice it to say, then, that the primitive teeth, imbedded as it were in the skin and stretched over the rod-like cartilaginous jaws, gradually assume a more intimate relation therewith, and sending down "fangs" became rooted in the jaw; while, at the same time, the covering of the body has gradually assumed other forms, so that, among the higher fishes and the rest of the vertebrates, all evidence of this peculiar origin has become obliterated. Furthermore, among each of the great groups of vertebrates more or fewer members have discarded teeth altogether, so far as the armature of the jaws is concerned, replacing these either with tooth-like bodies in some other part of the mouth, or with horny sheaths incasing the jaws.

Among the fishes, such substitutes are to be found in ossified, enamel-coated bodies, of varying shape,



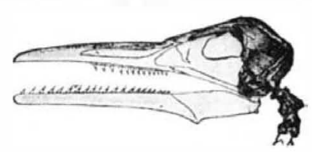
The almost complete skeleton of Pterodactylus antiquus (Sommerring), from the Lithographic Stone, Eichstadt, Bavaria (½ nat. size), showing the reduction of the teeth.

situated in the throat and known as pharyngeal teeth, as, for example, in the carps. On the other hand, it may be mentioned, some fishes have gone to the other extreme, and have, as if to secure themselves against all danger of toothlessness, devised the plan of welding all the teeth in the jaws into a solid mass, and fusing this inseparably with the jaws! And this perhaps to avoid the degradation of false teeth in the shape of the horny sheaths about which we are presently to speak, for in function these dental masses are the equivalents. No fish seems to have descended to such subterfuge.

Among the amphibia horny bosses simulating and performing the work of teeth are commonly developed during larval life, and are either replaced by minute teeth by the adult, or for the rest of life's journey they remain toothless as in the common toad.

But the amphibia, as befits their mode of life, seem to wobble a good deal in this matter of teeth; they halt, as it were, between two opinions. For, while some are toothless, others carry a few fine denticles on both upper and lower jaws, or they may be borne only on the upper or lower jaw respectively. They may in addition to these teeth on the jaws have teeth studding the roof of the mouth, or these last may be the only teeth in the head. Finally, there are some which seem to have contemplated the introduction of horny teeth during adult life, since the skin covering the roof of the mouth is therein thrown into ridges of hardened skin which may be "denticulated."

The reptiles, as befits their higher grade, are less uncertain in this matter. Among existing species the tortoises and turtles alone have discarded teeth, the jaws being incased, as in birds, in horny sheaths. That their ancestors were tooth-bearing creatures there can be little doubt; but to-day not even embryonic traces remain. We can reckon the more certainly on the truth of this conjecture since among extinct reptiles some very remarkable evolutionary phases in the substitution of teeth by horny casements for the jaws are to be met with. And nowhere is this more beautifully illustrated than in those old flying dragons—the pterodactyls. As may be seen in our text-figures the armature of teeth, in some species at any rate, was tolerably formidable, as for example in *Rhamphorynchus* and *Dimorphodon*. But, in course of time, these teeth gradually dwindled both in size and number, and were as gradually replaced by horn, till finally a horny beak



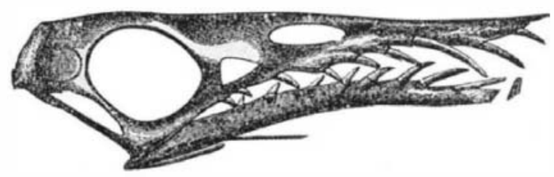
Skull and lower jaw of Ichthyornis victor, from the Cretaceous of Kansas, U. S. A. (½ nat. size. After Marsh.)

as in birds had come into being. A glance at the illustrations given herewith will enable the nature of this change to be realized more easily than a mere description thereof.

But this exchange, it is to be remembered, took place among many groups of reptiles, so far as the evidence goes, not in the least related. Among the dinosaurs, for instance, the same transformation took place, and, similarly, the change was gradual. But while among the pterodactyls the premaxillary teeth seem to have been the last to go, among the dinosaurs, in many cases, these seem to have been the first to disappear. *Ceratosaurus* may well serve as an example of what these creatures attained to in the matter of teeth, though even here, it will be remarked, the armature of the lower jaw is on the wane. And the same is true indeed of the upper jaw in so far as the hindmost teeth are concerned, but the decline is here less marked. In the giant *Diplodocus* all the teeth but a few skewer-like pegs in the front of the jaw have vanished completely, while in the *Iguanodon* the hindmost teeth are retained and the front teeth replaced by a beak-like sheath.

The pterodactyls and the dinosaurs were, however, as we have already remarked, not the only groups of these extinct reptilia which, more or less completely, contrived to exist without teeth. Among these old "fish-lizards," the ichthyosauria, for example, a beautiful series in the reduction of the teeth is met with, ending with the jaws of *Ophthalmosaurus*, wherein the adult was toothless, or at most, in some individuals, retained but a few minute teeth confined to the front of the jaw.

From the reptile to the bird is an easy step; and one would expect the ancestral birds to have tooth-bearing jaws. In the earliest known bird, *Archæopteryx*, well-developed teeth are met with; and the same is true of the cretaceous *Ichthyornis* and *Hesperornis*. But in the two last-named, both aquatic and fish-eating types, the toothless condition which was to prevail among modern birds was foreshadowed, inasmuch as the premaxillary portion of the jaw—the front portion of the upper jaw—was toothless and sheathed in horn. It would almost seem indeed as though these teeth were discarded grudgingly, at any rate among the fish-eating birds; since in another fossil—*Odontopteryx toliapicus*—though teeth are wanting the bony sides of the jaw developed tooth-like, angular bosses of bone which were incased in horn. And to this day certain fish-eating ducks adopt a similar expedient, though the bony cores to such horn "teeth" are wanting. Serrated edges to the beak-sheath are developed indeed among many groups of birds, some of which are certainly not fish-eaters. In the darter, which is piscivorous, teeth are replaced by short needle-like spines along the edges of the jaw, and a similar device



Right lateral view of the skull of Rhamphorynchus, from the Lithographic Stone of Eichstadt, Bavaria, to show the armature of teeth.

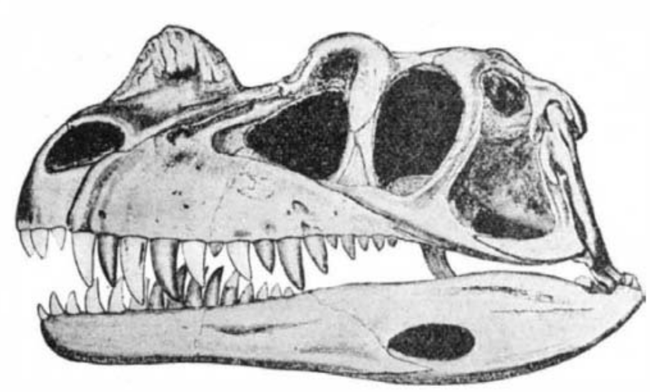
obtains among the insect-eating sun-birds.

Since birds retain many vestiges of ancestral and now obsolete and discarded structural characters, it is but natural to suppose that some trace of the now absent teeth should appear in the embryo. According to some authorities such vestiges are to be met with in the embryos of parrots. But the evidence so far submitted does not bear out the interpretation placed upon it. Nevertheless it is highly probable that such evidence will yet come to light, and we venture to prophesy that it will be furnished by the tinamous and ostriches. The present writer, indeed, long since drew attention to certain toothlike structures in the jaws of young tinamous, and hopes in the near future to demonstrate their true character.

Our survey has now brought us to the mammalia, which in point of interest in this matter of teeth and their substitutes exceed all the other vertebrates.

Primitively tooth-bearing, some have now become absolutely toothless, as in the anteaters and echidna; while in others the number of teeth has been greatly reduced. And this not by any sudden process, but as it were by slow starvation, each tooth as it passes the point of usefulness disappearing by a slow process of absorption. The last stages of their degeneration are carried out in secret as it were, the developing tooth being, so to speak, smothered before it cuts the gum. As a study in evolution by atrophy, it would be impossible to find a more striking series of examples than is to be furnished by the present-day whales. Beginning with the beluga, wherein this reduction is already far advanced, only nine teeth remaining on each side of the upper and lower jaws, we pass to the grampus with from three to seven teeth in the lower jaw only, and thence to the narwhal with but two in the form of the well-known tusks—generally only one of these is developed.

The whales again furnish us with one of the most extraordinary substitutes for teeth to be met with among the mammals—to wit, the baleen-plates of



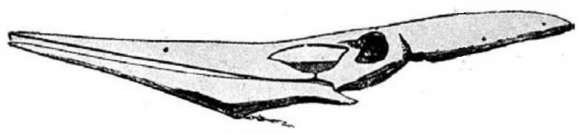
Left lateral view of skull of Ceratosaurus nasicornis (Marsh), from the Upper Jurassic, North America. (1/6 nat. size. After Marsh.)

"whalebone" whales. And it is therefore all the more remarkable that in this embryonic state the jaws contain their full complement of teeth, though these never cut the gum!

Finally we come to the remarkable case of the duck-billed platypus (*Ornithorhynchus*). As is implied by its popular name, the jaws of this creature bear a very striking resemblance to the beak of a duck, though really much more flattened than in any anserine bird. But, be that as it may, they are unquestionably bird-like, not only in shape, but in the absence of teeth. If the mouth be opened, however, there will be found

* Knowledge and Scientific News.

within two pairs of saucer-shaped horny pads, attached to the upper and lower jaws respectively. These serve as crushing pads for the trituration of small mollusca on which the animal feeds; and, since the creature is a mammal, these pads are obviously substitutes for teeth. So much, indeed, was always taken for granted. But in 1888, Prof. Poulton, of Oxford, actually discovered teeth in the jaws of an embryo, and later Mr. Oldfield Thomas, of the British Museum, had the good fortune to discover these teeth actually in use in immature animals. He further showed that they remained functional till worn out, by which time the horny



Left lateral view of skull of Pteranodon longiceps (Marsh), from the Cretaceous of North America (1/12 nat. size), to show the horny beak.

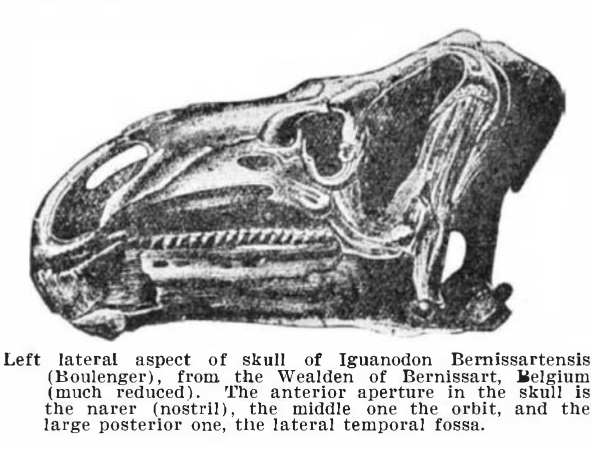
pads are large and hard enough to take their place!

The peculiarities of the teeth herein discussed have purposely been omitted, for these, as well as the manner of their use, seem to have no bearing on the law of survival. That is to say, animals of all grades, carnivorous or vegetivorous, show the same phases of evolution and devolution. But there seems to be some correlation between toothlessness and the persistence in time of the groups so denuded. Thus the earliest dinosaurs, ichthyosaurs, and pterodactyls, like the earliest birds, all have the jaws armed with teeth, and all in course of time replaced these teeth by horny casements. And this seems to be true also of the mammals, though to a less marked degree. It remains now for someone to read us the answer to this riddle.

RADIUM EMANATION AND THE DECOMPOSITION OF WATER.

At the end of last year Sir William Ramsay noticed an apparent decay of radium. He had sealed up some radium bromide in a bulb together with water—i. e., salt and water in the same bulb—and had observed a regular evolution of gas, hydrogen and oxygen from the water, proceeding at the rate of 30 cubic centimeters of gas per week. This evolution went on for nine months, when it ceased almost entirely. Sir William Ramsay concluded that either the radium salt had lost its capacity for decomposing water, or that the velocity of the reverse action, the recombination of oxygen and hydrogen to water, predominated over that of the decomposition. If the former assumption should prove true, then there might similarly be a time limit to the evolution of heat by radium and to the emission of rays in general. This abnormal cessation of the decomposition of water by radium is questioned by A. Debierne, one of the first workers in this field, in a communication recently presented to the French Academy of Sciences. The phenomena are very complicated, however, and it should be mentioned that, according to Rutherford and Tuomikoski, the rate of decay of the emanation is irregular.

The interesting feature in Debierne's new experiments is that he decomposed the water by the direct action of rays, keeping the radium salt and the water in separate glass vessels. The radium salt, he points out, emits α, β, and γ rays; the α rays would be absorbed by the glass walls of the vessels, and the β and γ rays would hence, in his experiment, directly affect the decomposition of the water, which seemed to continue at a uniform rate. The rate remained constant in his experiment, which extended over many months,

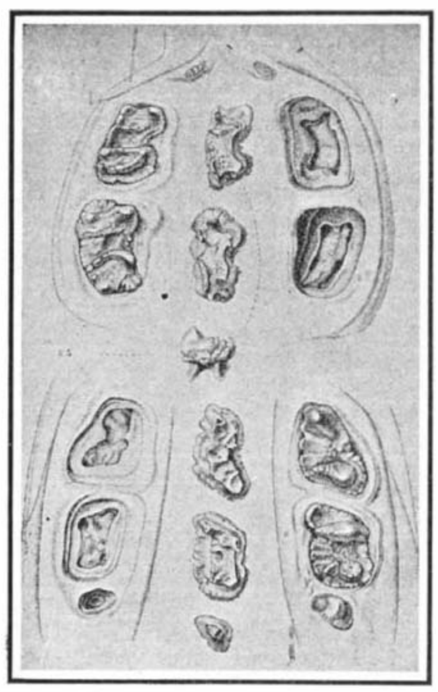


Left lateral aspect of skull of Iguanodon Bernissartensis (Boulenger), from the Wealden of Bernissart, Belgium (much reduced). The anterior aperture in the skull is the narer (nostril), the middle one the orbit, and the large posterior one, the lateral temporal fossa.

but there was finally a slight diminution in the rate, which might be accounted for in the following way: There is always an excess of hydrogen in the liberated gas, as Ramsay had already noticed; part of the oxygen, Debierne remarks, must therefore be absorbed by the water, oxides would probably be formed, and these oxides might in their turn absorb some of the hydrogen, so that the rate of gas production would apparently diminish. According to this reasoning, we are not obliged to believe in a material alteration of the rate in the course of time, which would be contrary to the general assumption of a constancy in radio-active phenomena. The mean rate of gas production is, according to Debierne, 0.115 cubic centimeter per gramme of radium per day—very much smaller than Ramsay's figure—and it would appear that about 1 per cent of the total radiant energy is absorbed by the water and transformed into chemical energy.

In a subsequent paper published in the Comptes Rendus, Debierne deals with the purification of radium emanation. Oxygen, hydrogen, carbon oxides, and nitrogen were removed from the emanation by successive treatments with heated metallic copper, copper oxide, phosphoric oxide, fused potash, and heated metallic lithium; the purified emanation was then liquefied between —175 and —150 deg. C., and a residue containing some helium, together with emanation, was pumped off. The liquefied emanation was finally quite free from neon and helium, and the mean volume of emanation in equilibrium with 1 gramme of radium was found to be 0.58 cubic millimeter, while Rutherford had recently found, by a different method, 0.57 cubic millimeter. The agreement with Rutherford as to the half-period of the emanation—3.81 days according to Debierne, 3.75 days according to Rutherford—is equally remarkable. Debierne's emanation yielded spontaneous electric discharges, attributed to the accumulation of electric charges by the α and β particles in the insulating vessel, which, when made of lead glass, turned violet.

Rutherford's first-mentioned value of 0.57 cubic millimeter was defined by assuming that one atom of radium emits one α particle, and then becomes one atom of emanation; the number of α particles emitted per second was known from the experiments of Rutherford and Geiger. According to Ramsay and Cameron, 1 gramme of radium should yield 7.07 cubic milli-

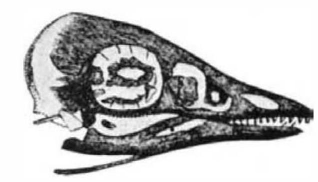


Palate of Duck-billed Platypus (after Poulton), showing the teeth in position, on the roof of the mouth (left-hand top figure), and in the lower jaw (lower figure, right-hand), the horny pads which succeed them show the sockets of the displaced teeth, seen, from their roots, down the middle of the picture.

meters (instead of 0.57) of emanation; and Rutherford considers that Ramsay's emanation contained 80 per cent of foreign matter. One of these foreign substances, very difficult to remove or to keep out, is carbon dioxide, which, it will be remembered, Ramsay found in several of his experiments on thorium emanation; this observation induced him to suggest a degradation of thorium into carbon. By exercising the greatest care, lubricating his stop-cocks with phosphoric acid, and making the emanation stand for twenty-four hours at the time over potassium hydroxide, Rutherford finally obtained a radium emanation which hardly showed the spectrum of carbon dioxide any longer, while bright lines (probably of the emanation itself) were seen. When the emanation was left for eleven days in its capillary tube, the volume of the emanation increased again, and the bright lines of helium then became quite striking.

We may also refer to a further paper by E. Rutherford and T. Royds, published in the Philosophical Magazine, like several others of their communications. The object of this research was to prove that the α particle really consists of an atom of helium plus a positive charge. The purified radium emanation was compressed in a capillary tube, whose glass walls, 0.01 millimeter in thickness, would be impermeable to helium, but would allow the α particle, as well as radium A and radium C to pass into the annular space between the capillary and an outer tube of stout glass. The gas collecting in this outer tube was spectroscopically examined. After twenty-four hours no trace of helium could be detected in that gas; but after six days the helium lines were distinct. That helium, Rutherford suggests, must have been formed by the α particles which had traversed the inner capillary tube and which had slowly lost their charge. From other experiments, in which the outer glass tube was replaced by a cylinder of lead foil, it would further appear that the α particles were driven into the outer glass, and slowly given up again by the glass, while they would more readily escape from the lead; hence the slow appearance of the helium in the jacket.

That Rutherford and Royds question the transformation of radium emanation into neon, which had been suggested by Cameron and Ramsay in their transmutation experiments, has already been mentioned in con-



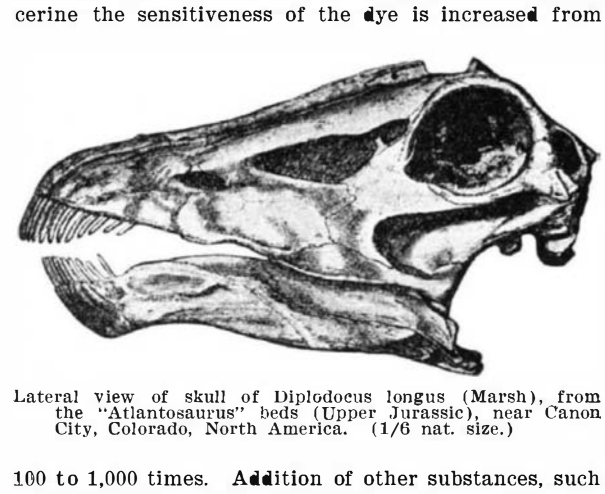
Skull and lower jaw of Archæopteryx siemensi, showing teeth, from the Lithographic Stone (Upper Jurassic) of Eichstadt, Bavaria. (Nat. size. After Dames. Original in Berlin Museum.)

nection with our reports on the Dublin meeting of the British Association last year. Particulars of the experiments on which they base their objections have since been published.

Leakage of air into glass apparatus which are worked for weeks and months is always likely, and Rutherford and Royds find that if only 1/5 cubic centimeter of air had found its way into Ramsay's apparatus, the flashing up of the neon line noticed by Ramsay would be accounted for. We may hence sum up that the production of helium from radium must be accepted, but that the other suggested transmutations have not been confirmed. The exceeding difficulty of such gas isolation experiments is well brought out by some quite recent researches of Franz Fischer, of Berlin. He prepared argon from air with the aid of calcium carbide (which binds the nitrogen), liquefied it, found it pure, and exposed the liquid argon to the spark or arc discharge with electrodes of cadmium (and other metals); but the apparent argon compound thus produced proved to be cadmium nitride. Some nitrogen had evidently leaked into the apparatus.—Engineering.

THE SENSITIVENESS OF DYES TO LIGHT.*

In the course of some experiments on the use of the ordinary dyes for photographic light-filters, observations were made of the permanency of the coloring matters. It was found that gelatine films which had been stained with chemically pure dyes made in the Hoescht works, and selected by Dr. E. Konig, showed a high degree of permanency, inasmuch as they could be exposed for an hour at a time in direct sunlight, without suffering the slightest perceptible alteration. But a quite different action was noticed with these same dyes when the films contained a relatively small proportion of glycerine. Addition to this substance, which might be presumed to have been quite inactive, greatly affected the permanency of the dyes toward light. Thus its action was very noticeable in the case of methylene blue, pheno-saffranine, and scarlet, less so in the case of crystal-violet and rose Bengal, and apparently *nil* in the case of patent-blue, echt-rot, and tartrazine. Using 10 grammes of gelatine and 3 cubic centimeters of glycerine, films of methylene-blue may be made which become completely colorless within an hour when exposed to direct sunlight, while the same film, without glycerine, undergoes no change whatever, exposure under a paper scale built up in gradation strips showing that by the addition of glycerine the sensitiveness of the dye is increased from



Lateral view of skull of Diplodocus longus (Marsh), from the "Atlantosaurus" beds (Upper Jurassic), near Canon City, Colorado, North America. (1/6 nat. size.)

100 to 1,000 times. Addition of other substances, such as salts of arsenic acid, allow of the sensitiveness being still further increased, so that an exposure of a few minutes in sunlight leads to a complete bleach-out action. In this case the addition of glycerine is so slight that the film may be said to dry, having no sign of dampness nor feeling of stickiness.

By these methods colored prints on paper can be prepared, although, unfortunately, they have the property that the parts bleached in the light rapidly reassume their original blue color. If a print of this kind is

* A note in the Wiener Mitteilungen for the translation of which we are indebted to the British Journal of Photography.