The Periodic Growth of Scales in Gadidæ as an Index of Age.

By

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(With Plates I.–VIII., and one Figure in the text.)

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I. Introduction.

This work is a continuation of my preliminary paper on the same subject, which was published in a former number of the Journal of the Association (vol. vi., p. 373, January, 1902).

I must firstly express my indebtedness to those who have aided me in my work. I am signally indebted to Mr. Garstang, who, about two years ago, suggested that I should endeavour to extend to marine fishes this newly revived though really old hypothesis, that the age of certain fishes might be determined by means of annual rings on their scales, an hypothesis which Dr. Hoffbauer had previously shown to be true for some fresh-water fishes, such as the carp. To Dr. E. J. Allen I am indebted, not only for placing all the possible facilities of the Plymouth Laboratory at my disposal, but also for reading the manuscript and proof-sheets. For the latter I am all the more indebted to Dr. Allen, in that, as I write, I am just on the point of leaving this country to take up a new biological appointment at Cape Town. I would further express my obligations to Professor McIntosh, Dr. T. Wemyss Fulton, and Dr. H. M. Kyle, who generously helped me in securing additional specimens. I must add that without the aid of a Government Grant, awarded through the Royal Society, this work could not have been accomplished in its present form.

This paper consists of two parts: the first part contains a review of the literature on fish scales, more especially so far as that bears on the subject of my investigation; the second part is composed of statistics dealing with the size, the number of growth-lines and annual rings in scales from fish of all sizes, and captured at the various seasons of the year. The accumulation of the necessary statistics for this second portion of my work has been an arduous and lengthy task, involving, as it has done, exact measurements of hundreds of scales and a more superficial observation of thousands of others.

II. Summary of Literature.

I may firstly notice that, shortly after the invention of the microscope, Borello wrote a brief description of the microscopic appearance of a fish scale, and added a diagrammatic figure of the same.*

About a hundred years later, Hooke, in his *Micrographia*, gave a very brief description, but a fairly exact figure, of the scales of the sole.†

We are indebted to Leuwenhoeck for several interesting notes on the development and structure of scales.‡ In regard to the growth of scales, his first idea was that each year the scales increased in size by adding a new zone or circle to the pre-existing scale. Later, however, he abandoned this view, as in examining certain scales he observed that those of old fishes are very thick, much thicker than they would necessarily be if their mode of increase was simply by the addition of a new circle or zone each year.

He came to the conclusion that the portion which he had at first taken for a new zone disposed round the primitive scale was simply the most external part of a new scale, the part which exceeded the old scale in size, and that all these scales were intimately welded together.

* Borello, 1566. [For detailed references see Literature, p. 106.]
† Hooke, 1667. ‡ Leuwenhoeck, 1696.

In order to explain the formation of superimposed scales, Leuwenhoeck believed that the growth of scales, as that of hair, feathers, horns, and trees, ceases for a very short period at the end of the first year, and that scales are afterwards formed beneath and add themselves to the first. As the scales of a two-year-old fish exceed those of a one-year-old fish in size and dimensions, it follows that the scale of a two-year-old fish is partly covered by the first-year scale and extends beyond it. The same takes place for the following years, and thus the scales of a ten-year-old fish are composed of ten scales, secondarily superimposed the one upon the other, and fused so intimately with one another that they cannot be easily separated without tearing the scale into pieces. If, in the scales of fishes, new scales did not weld themselves each year to the old scales, then the scales of very large fish would of necessity be very thin and fragile. Leuwenhoeck restated these views in a later paper.*

Réaumur made a study of the silvery substance of scales, sometimes known as "l'essence d'Orient." † He stated that this substance consists of a mass of an infinite number of small and very irregular bodies. These bodies are extremely thin, but of great solidity. He found this substance present almost solely on the internal surface, not on the external surface, of the scale. He held that this substance is covered over by membrane, and contained in vessels or tubes which extend in a direction transversely perpendicular to the length of the scale. Réaumur affirmed that this silvery matter contributed directly to the growth of scales. He agreed with Leuwenhoeck that each scale is composed of an indefinite number of layers, of which the largest are those nearest the body of the fish. Speaking of the concentric lines, Réaumur wrote "that they occupy the border of each layer, of which they mark the limit, and that they indicate the different degrees of growth in scales, just as the analogous markings indicate the growth of shells."

As to the radiating grooves in scales, Réaumur believed that they lodged blood-vessels. He also gave a good description of the scales of the lateral line, pointing out that scales from that region have a small canal on their external surface. These small canals abut end to end, thus forming a continuous channel, which apparently serves to carry away the mucus formed on the bodies of various fishes.

Roberg reproduced a figure of the scale of the eel, previously given by Leuwenhoeck.‡

In his Memoir on the Carp, Petit dealt with the following points in connection with their scales, but only in a very brief manner: the mode in which scales overlap each other, the dimensions of scales in different regions of the body, the mode in which scales are enclosed in the skin, the furrows (*sillons*) on the upper surface of the scale, the silvery matter on the lower surface, etc. He, however, gave a much more detailed description of the scales of the lateral line. §

A few observations on scales are found in the writings of Schaeffer. He also gives figures of scales from five different species of perch. He notes the external characters of scales, and their variation in different parts of the body, but does not go into their detailed structure nor development. ||

* Leuwenhoeck, 1716. † Réaumur, 1716 and 1718. ‡ Roberg, 1717.

§ Petit, 1733. || Schaeffer, 1761.

Broussonet demonstrated the presence of scales in a number of genera of fish in which their existence had either previously been denied or held in doubt, for example Cepola, Remora, Ammodytes, Anguilla, Scomber. His descriptions are very brief, and the paper is not of great importance.*

We owe to Heusinger the first attempt at a classification of fish by means of their scales.† He divided fishes provided with scales into five groups:—

I. Fish with small scales entirely hidden in skin (Anguilla, Muræna, Blennius, Murænophis).

II. Fish with scales properly so called (Carp, Esox, Salmo).

III. Fish with scales strongly toothed at their free margins (Chætodon).

IV. Fish provided with osseous scales (Knochenschuppen). These scales resemble those of Group II.; but they have so much calcareous matter as to resemble hard teeth. They are not usually imbricated, but are isolated or simply contiguous; their surface is frequently furnished with spines (Lepidosteus and several species of the genera Trigla, Cottus, Silurus, Gasterosteus, etc.).

V. Fish with osseous plates (Knochenplatten). These plates form a solid cuirass round the fish (Ostracion, Diodon, Syngnathus, Hippocampus, Accipenser, etc.).

Selachians are not comprised in the preceding five groups. Heusinger places them in a separate division characterised by the "mode of conformation of the spiny formation," whose structure approaches to that of teeth.

Heusinger also gives a succinct description of true scales, and in regard to their structure agrees with Agassiz in regarding each scale as composed of superimposed lamellæ or layers.

Kuntzmann's paper ‡ is of importance chiefly because it contains the germ of an idea which Agassiz later developed more fully in his *Classification des Poissons.* In his paper Kuntzmann opposes the views of Schaeffer, who had emphasised the differences between scales of the same fish. Kuntzmann held "that though one does not easily find absolutely similar scales on the same species of fish, yet the scale of each species has some characteristic feature, and that an examination of scales may enable one to acquire a more exact knowledge of species, and that one may identify some genera and even some species simply by an examination of their scales." He compares scales to the leaves on plants, in which, although there is frequently quite a degree of variation among the leaves of the same species, still one may often recognise the species of plant by means of its leaves.

Kuntzmann experimented with scales in regard to their indestructibility in water, and showed that after prolonged immersion in water they were not softened to any marked degree.

He opposed the opinion of Leuwenhoeck as to the concentric lines on the upper surface of the scale indicating the age of the fish. He maintained that the scales of an old carp do not show a larger number of concentric lines than those of the young carp (see Hoffbauer). As to the mode of scale growth, Kuntzmann agreed in the main with the views of Réaumur. He regarded the small quadrangular plates (described by Réaumur) on the internal surface of

* Broussonet, 1787. † Heusinger, 1823. ‡ Kuntzmann, 1824.

the scale as a precipitate, a deposit of mucus, which contributed directly to the formation of scales. He differed, however, from Réaumur as to the situation of these quadrangular plates later, affirming that they were contained between two membranes on the internal surface of the scale, and not in vessels. He held that growth does not take place at the edge, but over the entire scale, and that this mode of growth is a consequence of the structure which the scale shows at the time of its first formation, for the scales of a young fish and those of an old fish are not essentially different except in size. He thinks that this mode of formation allows one to explain the difference between scales of different species, especially the difference of the concentric lines, which may be wide or narrow, straight or curved, entire or interrupted in the different species.

Kuntzmann worked out a classification of scales into seven classes, remarking at the same time that quite gradual transitions existed between these classes, and that certain scales might equally well be placed in one class as in another. His classes are the following :—

I. *Membranous scales* (*hautigen Schuppen*). Scales which do not show concentric lines (*Gadus lota*).

II. *Semi-membranous scales* (*halbhautigen*). Scales with a membranous posterior portion, but with the anterior portion marked out by incomplete concentric lines, crossed over by other lines running longitudinally (*Clupea harengus*).

III. *Simple scales* (*einfachen*). Scales with concentric lines covering their entire surface without those lines forming any definite design by other lines crossing over them (*Salmo salar*).

IV. *Scales with a design* (*gezeichneten*). Scales in which the concentric lines on the scale surface form a regular design due to the arrangement of the same (*Murœna anguilla*).

V. *Scales divided into several regions* (*gefelderten*). Scales on which there exist numerous ornaments which parcel out the scale into four well-defined fields. These diverse fields, usually triangular in shape, meet at a point, which is usually at the same time the centre of the concentric lines (*Cyprinus carpio*).

VI. *Scales with prickles.* These scales are also frequently divided into four fields. The posterior field bears spines on a more or less extended portion of its surface, or sometimes only at its free border. These spines fall off on prolonged maceration, showing that they are not really portions of the scale, but arise from the skin which covers the scales. These spines also fall off naturally at certain seasons, and others take their place. "This fact seems to establish a kind of moulting, such as occurs in Amphibia." Examples—The scales of *Scorpœna.*

VII. *Spinous scales* (*gedornte*) are also divided up into several areas or fields. The spines are in this case, however, true prolongations of the scale, and do not become detached on maceration. Example :—*Perca lucioperca.*

Kuntzmann gives a short description of each type of scale with a corresponding figure. Although the preceding classification is interesting, yet it leads to an artificial comparison.

Ehrenberg described the crystals of silvery matter previously described by

Réaumur. Along with his description there is an analysis of this substance by Rose.*

Agassiz expressed himself in the following manner in regard to the structure and development of scales:—†

"Scales are contained in mucous cavities or in small sacs formed by the 'chorion,' to which, however, they do not adhere by vessels. They are formed of lamellæ, of horny or calcareous layers, superimposed the one on the other, which are secreted at the surface of the chorion; these layers attach themselves successively to the inferior surface of the preceding, to which they weld themselves by layers of hardened mucus. In order to obtain a true idea of this development, it is necessary firstly to observe it in those genera of fish in which the scales appear to show these arrangements in the simplest state, for example, in the Eels, the Blennies, Cobitis, and Leuciscus. It is easy to assure oneself that the concentric lines of the anterior border and those of the posterior border are continuous the one with the other."

In order to support his theory, which after all is none other than that of Leuwenhoeck, Agassiz appealed to the following:—

"After having macerated scales for some time in water, one can easily," he says, "divide them up in a large number of layers or plates of greater or less thickness, and of different size, but all of which have the form of the scale. These plates are superimposed in such a manner that the smallest occupy the centre of the scale, and form its interior part, while the largest, bordering the preceding, are successively welded to their inferior face. Thus one sees that the concentric lines which are visible on the exterior surface of scales are simply the borders of plates which compose them."

The radiating grooves (*sillons rayonnants*) Agassiz regarded as channels at the margin of the external surface, which connect one layer with another, and multiply during the growth of the scale. In this work Agassiz introduced his well-known classification of fish into four orders according to the nature of their scales, the Placoid, Ganoid, Ctenoid, and Cycloid orders.

Mandl,‡ well known as the opponent of Agassiz, held widely different views in regard to scale structure and development from those of all the authors previously mentioned.

He attempted to establish the existence of an internal life and true organisation within the scale. According to him, most scales are composed of two superimposed layers, superior and inferior. The superior layer shows the structure of cartilage with corpuscles, the inferior layer consists of lamellæ which recall the structure of fibrous cartilage.

In the *superior layer* he describes longitudinal canals, cellular lines, and corpuscles.

Longitudinal Canals. Under the term "*longitudinal canals*" he describes the grooves which radiate out from the centre to the periphery of the scale. According to Mandl, these lines show all stages of formation, from that of a simple groove to that of a perfectly formed canal. These canals lead to a common point, the focus, which is a centre of nutrition, a point where tissue

* Ehrenberg, 1833. † Agassiz, 1834. ‡ Mandl, 1839.

is found developing. Mandl thought that these canals serve for the transport of nutritive material from the skin towards the centre of nutrition, in other words, that they fill the rôle of true vessels containing nourishment.

The Cellular lines. Under this term Mandl discusses the concentric lines or ridges parallel to the contour of the scale. He does not agree with previous authors in regarding these lines as the projections of secreted and superimposed layers. According to him, these lines owe their origin to special cells which originally form themselves on the superior surface of the scale; gradually these cells amplify and elongate, and finally come to represent cellular lines.

Corpuscles. Mandl is the first author to describe definite corpuscles in the tissue of scales. He describes those corpuscles as of a yellowish colour, and of an oblong, more or less elliptical form. They diminish in size towards the edge of the scale, showing there only a granulated appearance similar to that which one notices sometimes in the vicinity of the longitudinal canals. These corpuscles are usually arranged in a very regular way, sometimes crossing one another in such a manner as to form a cross. Under the action of acids they become transparent.

These corpuscles are contained in a definite tissue which is situated above the inferior surface of the scale. This tissue is an amorphous tissue like that in which the corpuscles of bone are deposited. The tissue constituting the superior layer of scales thus approaches that of cartilage with non-ossified corpuscles.

Inferior layer of scale. Beneath the layer with corpuscles is found the inferior layer, which is a fibrous layer built up of fibrous lamellæ, in which the fibres cross one another at regular angles, but in which the fibres all follow the same direction in the same lamella. This arrangement approaches that of fibrous cartilage. This inferior layer is thickest at the focus (*foyer*) of the scale, and thinnest at the borders; it is this which forms the foundation of the longitudinal canals in the vicinity of the border of the scales.

Mode of scale formation. Mandl endeavours firstly to establish a distinction between the formation of the superior and inferior layers of scales. According to him, the superior layer, composed of cells, corpuscles, and of the fundamental substance which contains them, develops by growth, which takes place at the periphery round the cellular lines.

The inferior lamellæ increase by the formation of new lamellæ beneath the preceding. The elements necessary for the formation of these lamellæ are brought by the longitudinal canals. The old lamellæ being the smallest, this explains why the thickness of the scale ought to increase in degree as one approaches the focus (*foyer*).

"Si nous voulons appliquer les résultats que nous avons obtenus dans l'étude de la structure intime des écailles, à l'explication de la manière dont elles se forment, nous verrons tout d'abord qu'il importe de bien distinguer la formation de la couche supérieure, et celle de la couche inférieure. La première, composée de cellules et de leurs bases avec le tissue qui contient les corpuscles, prend son dévelopement par des accroissements qui ont lieu dans la périphérie, autour des lignes cellulaires; au moyen, de pareits accroissements, ils forment, non-seulement plusieurs lignes cellulaires, mais les canaux longitudinaux eux-mêmes se trouvent allongés. Il est très probable que ces lignes cellulaires ne se forment pas, seulement, l'une après l'autre, mais que plusieurs lignes sont produites simultanément ; nous en trouvons une preuve dans les écailles, qui dans leurs accroissement successifs, conservent les espaces marginaux, et dont les lignes cellulaires ou les cellules sont ainsi séparées en plusieurs groupes, nous citerons par exemple les écailles de cobitis fossilis. Mais cet accroissement dans la périphérie n'expliquerait nullement, la grande épaisseur du milieu ; nous en trouverons la cause dans la formation de la couche inférieure. Nous avons vu que celle-ci est composée de plusieurs lamelles. À chaque accroissement se forment toujours des nouvelles lamelles : les canaux longitudinaux, qui parcourent toute l'écaille, apportent les sucs nécessaires pour qu'une formation uniforme d'une nouvelle lamelle puisse s'opérer dans toute l'étendre de l'écaille. Il s'ensuit, que les anciennes lamelles étant plus petites, l'épaisseur doit s'augmenter, à mesure que l'ou se rapproche du foyer."

As to the use of scales for purposes of classification, Mandl says that up to the present " we have found definite and characteristic forms for each family," and that further research on a sufficient number of individuals would decide whether this might also be applied to genera and species. Mandl's views were thus totally at variance with those of Agassiz, and the latter answered in a letter addressed to l'Académie des sciences,* in which he attacks the results announced by his opponent. Agassiz concludes this letter by saying that the description which he had previously given of the structure of scales was correct, and that Mandl's method of viewing the subject was altogether wrong.

Mandl replied to Agassiz's letter by a counter letter, also addressed to l'Académie.† He reiterated that scales are organised bodies, and consist of true living tissue capable of nourishing itself and growing by intussusception. He replied to each of Agassiz's criticisms by a new affirmation to the opposite effect, and accused Agassiz of having badly understood or misinterpreted some of his points.

In the same year Agassiz published a fairly extended memoir,‡ in which he takes up the facts as stated by Mandl, one by one, and subjects them to the severest criticism.

After some points relating to the structure of the skin, Agassiz deals with the following :—

(*a*) Longitudinal canals, (*b*) cellular lines, (*c*) the corpuscles, (*d*) the fibrous layer, (*e*) the focus, (*f*) the teeth.

Firstly, Agassiz denied the existence of true longitudinal canals, and the rôle of these so-called canals as having the function of nourishing the scale.

As to the cellular lines, Agassiz emphatically denied the presence of cells, and wrote that Mandl had been deceived by an optical illusion. As to the corpuscles, Agassiz maintained that they are not situated in the thickness of the scale, as stated by Mandl ; but on the contrary, close to the superior and inferior surfaces, for if one slightly scrapes one of these surfaces or, after a slight

* Agassiz, 1840. † Mandl, 1840. ‡ Agassiz, 1840.

maceration, raises some of the lamellæ, the corpuscles disappear. Agassiz thought that the corpuscles beneath are lamellæ incompletely formed, and those above are lamellæ which have been broken down through the friction of scales against one another. As to the fibrous layer, Agassiz believed that this layer, which Mandl described as serving for the foundation of the cellular substance of scales, has as little existence as the cells themselves; in other words, that its supposed existence was founded on an error of observation, as all fibrous tissues (tendons, cellular tissue, etc.) produce gluten on boiling, yet well-cleaned scales never produce that substance. Agassiz maintained that scales do not show two distinct layers, but that the superior and inferior layers have the same composition. He thought that the fibres described by Mandl were due to a tearing of the younger and less consistent inferior lamellæ, which gave rise to the appearance of fibres; but which was none the less an optical illusion. According to Agassiz, the focus is simply the oldest part of the scale, in which the superior lamellæ have been worn away by friction or exfoliation. Altogether, Agassiz maintained that the material which Mandl had brought forward as to the detailed structure of scales was quite erroneous. Agassiz's idea as to the mode of scale formation may be summarised as follows:—

"The scales of fishes are epidermic secretions, analogous to that of nails. As in nails, the scales are composed of exceedingly thin lamellæ of a horny nature, superimposed the one on the other in the order of their formation. The secreting organ is the epidermic pouch, in which the scales are ensconced at their anterior borders. The newly formed lamellæ are very soft, but of the same composition as the oldest lamellæ. The pouch increases in such a manner that the newly formed lamellæ are always larger than the older. The concentric lines are reflexed parts of the borders of superimposed lamellæ, and these lines are more numerous in old than in young fish. Scales disintegrate or waste chiefly round the focus by friction of the scales among themselves or by exfoliation. The focus and corpuscles on the external surface are simply results of this wearing down; one does not find them in non-imbricated scales, as in those of the eel, for example. By means of sections one sees that scales are composed of lamellæ, and that there are marks which correspond to concentric lines. The so-called teeth or notches are simply indentations of the posterior border of the lamella."

In the following year, Peters* gave a critical review and summary of the observations of Mandl and Agassiz. This author firstly gave some general considerations on the structure of the skin of fishes. In a fresh-water fish, one finds the following layers in the skin covering the scales:—

1. An epidermis composed of squamous cells (the latter being very abundant in the mucus of fishes).

2. A layer of pigmented cells.

3. The skin proper, a layer composed of fibrous connective tissue containing fatty globules.

4. An exceedingly thin membrane immediately on the external surface of the scale, but distinct from the skin. On this membrane are seen concentric

* Peters, 1841.

grooves and longitudinal ridges corresponding to the concentric ridges and longitudinal grooves on the scale. This membrane consists of thin crossed fibres, the intercrossing of which results in the indentations of the concentric ridges. The constituent fibres swell strongly under the action of acetic acid, a character which evidently belongs to fibres of connective tissue. The superior or external portion of the scale shows, moreover, a very fine inseparable layer, which shows the presence of fibres under the action of acetic acid, and which it is difficult to destroy by combustion. These intimate connections between skin and scale enable one to see how, during growth, the appearance of the scale surface may be modified without exfoliation taking place.

According to Peters, the scale is not formed in the epidermis, but in the skin itself; in that case the scale cannot be simply a horny secretion of the epidermis.

Peters agrees with Mandl in admitting the existence in all scales of a very soft lamellated inferior layer consisting of fibrous cartilage; he disagrees with Agassiz as to the number of lamellæ corresponding to the number of concentric striæ on the upper surface. He held that Agassiz had not sufficient proof of the non-existence of cartilage in scales, and did not believe in his statement as to the horny nature of scales.

As to the corpuscles, he maintained that these were found, not on both surfaces of the scale, as stated by Agassiz, but only on the inferior surface. He regards the corpuscles as special elements, and not as being due to incompletely formed lamellæ or to the wearing down of these thin layers. Corpuscles of some solidity show a granular appearance towards the border of the scale, and give rise to the asperities existing on the posterior border of many scales (Perch). Towards the centre of the scale one finds beneath the elliptical forms quadrangular corpuscles which are arranged in regular series, and give rise to spines. These spines are not, as Mandl supposed, comparable to true teeth. Peters believed that scales could not afford a proper basis for a rational classification, showing that two kinds of scales, cycloid and ctenoid, occur in the same fish (*Pelamys sarda*).

As to the superior or external layer of the scale, Peters realised much difficulty, especially in attempting to explain the origin and meaning of the concentric lines and radiating canals.

The superior layer, he said, does not usually show any distinct elements, though sometimes one can recognise in it the same fibres and the same corpuscles as in the inferior layer; but never with the same degree of distinctness and clearness. He did not believe that the concentric striæ represented the borders of superimposed lamellæ or plates of the scale, in as much as the striæ are not always parallel to the free border, but are sometimes perpendicular to it. For example, in *Alepocephalus rostratus* the striæ are only disposed concentrically in the posterior third of the scale, while in the remainder of their extent they run straight forward, parallel the one to the other. He agrees with Agassiz in refuting the statement of Mandl in regarding the radiating canals as serving for the nutrition of scales, and regards them rather as sutures rendering growth possible in all directions. He adds that these sutures are not only found running out from the centre in the direction of the periphery, but sutures are sometimes disposed concentrically (Ophidium, Sudis, Rypticus, Heterotis, etc.).

Peters denies the existence of osseous corpuscles in ordinary scales, but admits the fact of their presence in Polypterus and Lepisosteus.

In his paper on the embryology of the salmon, Vogt brings forward some facts relating to the development of scales.* He states that the scales do not show themselves till three months after hatching; that the concentric plates, so numerous in the scales of the adult salmon, are relatively few in number in the young fish; but that the lines which indicate the borders of different plates are just as continuous in the young as in the old scale, and thus in no way indicate formation from isolated cells. He notes that the central focus is frequently smaller in the young as contrasted with the adult worn scale.

Müller issued a paper on Ganoids and natural classification of fishes.† In part of this paper the author deals with some points relating to the taxonomic value of the characters of scales. He held that the differences between the scales of Cycloids and Ctenoids is of little importance, and can only be useful for purposes of classification in a very limited way. ‡ Later Vogt issued another paper, § in which he discusses the value of the characters of scales in distinguishing different orders of Ganoids.

In the *Manual of Comparative Anatomy*, by Siebold and Stannius,‖ the latter makes some statements regarding scales. He writes that scales cannot be regarded as horny epidermic formations, and that it is impossible to ignore the presence of a substance on the lower scale surface possessing a fibro-cartilaginous texture and the existence of osseous corpuscles in some scales. He does not admit that scale growth takes place only by means of super-imposed layers, and regards it as doubtful whether it would be right to take the different forms of scales exclusively as a basis for classification.

In a paper by Dareste on the classification of Plectognathes, we find some observations on the scales of fishes belonging to this order.¶ In regard to the integuments of Diodons and Tetrodons, he writes that in these we have not scales, but spines, which are fixed in the skin by roots of a horny nature. The spinous portion is very closely analogous to the ivory of teeth, and contains as in these tubules which radiate out in all directions. The integument of Triodons differs from that of Diodons and Tetrodons in possessing true scales, comparable on the whole to those of osseous fishes. The external border shows indentations similar to the ctenoid condition as described by Agassiz. The cuirass of Ostracions results from the union of rhomboidal plates placed side by side, and which possess an inferior layer of a horny nature and a superior layer of osseous substance possessing calciferous tubes which recall the structure of teeth.

Dareste, in another paper on *Blochius longirostris*,** gives some considerations on the value of scales as characters in classification. He would not give them the rôle of dominating characters.

Williamson published an important paper on the structure and development of the scales and bones of fishes.†† Writing in 1873, Baudelot claims

* Vogt, 1842. † Müller, 1844. ‡ Müller, 1843. § Vogt, 1845.
‖ Siebold and Stannius, 1849. ¶ Dareste, 1850.
** Dareste, 1850. †† Williamson, 1851.

that the latter paper is "one of the most important which has been published on the scales of osseous fishes."

Williamson brought forward important general views relating to the mode of composition of the scales and of the other hard parts in fishes. He endeavoured to show that scales, teeth, chondrified and membranous bones, etc., are not really formed of tissues of an entirely different nature, but of tissues which pass the one into the other by gradual transitions. Williamson commences his paper by a critical review of Mandl and Agassiz's work. He regarded Mandl's view of scale formation as given on page 7 as being more correct in some respects than that of other writers, but as being built upon a false foundation on account of his having mistaken solid calcareous granules for cells. He regarded Mandl's description of the inferior layer as correct, but denied the existence of longitudinal canals as described by him.

Williamson points out that although Agassiz at first refuted Mandl's statement as to their being two layers in scales, he subsequently acknowledged that each scale really consisted of two different strata. Williamson regarded Agassiz's views to be as little tenable as those of Mandl. He says that while Agassiz regarded the lower layer of the scale "as a horny substance, an exuded secretion from the sac into which he considers the lower and anterior portions of the scale to be fitted," it is really a fibrous substance.

He says that Agassiz has failed "to detect the existence of two distinct structures in the upper or calcified part of the scale," and that in regarding the corpuscles in the middle of the scale not as true corpuscles, but rather as due to some solution of continuity between the upper and lower tissue, he has quite mistaken their character. According to Williamson, cycloid and ctenoid scales consist of three layers, inferior, median, and superior.

The *inferior layer* consists of numerous membranous laminæ arranged in parallel horizontal lines. These laminæ are most numerous in the centre of the scale, and decrease in number as we approach the periphery, until finally only one is present. Each of these membranous laminæ is composed of numerous fine fibres, all of which run parallel with one another in the same lamina. Numerous isolated lenticular calcareous bodies are to be observed imbedded amongst these membranous laminæ. These calcareous bodies arise as a result of the calcification of the membranous laminæ, and appear firstly as small calcareous atoms, which grow in size by the addition of successive concentric laminæ to their external borders. "The growth in size of cycloid and ctenoid scales takes place by the successive addition of membranous lamellæ on the inferior face of those which have been previously formed, each new plate being larger than the preceding."

The median layer of the scale is mainly built up of a mass of similar lenticular calcareous bodies which unite with one another as they increase in size, frequently also losing their original lenticular shape during this process of coalescence.

This median layer of the scale decreases in thickness as one proceeds from the centre to the periphery until at last it disappears altogether, the calcareous layer being not only thicker, but now consolidated towards the centre of the scale. After the calcareous granules have become fused and consolidated together, the median layer thus formed is split up into horizontal laminæ which agree in their direction with the membranous laminæ previous to calcification. The laminæ also exhibit a number of vertical cleavages or fissures. "The middle layer then is produced by the formation and coalescence of the small lenticular bodies, through the agency of which the calcification of the membranous laminæ is effected. This calcification permeates the entire extent of the upper and earlier-formed lamellæ, whilst, with the exception of a few isolated granules, it has been confined to the margins of those which are inferior and of more recent growth."

The superior layer of the scale differs both in structure and in mode of origin from the median and inferior layer. This superior layer is the one by various modifications of which all the ridges and tubercles seen on the surfaces of scales are produced. In vertical section it frequently shows an undulating outline and has traces of a lamellar formation (the lamellæ being homogeneous and devoid of structure), the more external being parallel with the upper surface of the section. The radiating lines (nutrient canals of Mandl) are produced simply by the absence of superficial tissue along their course. While these radiating lines are not nutrient canals, as was supposed by Mandl, neither do they pass through the entire calcareous portion of the scale and reach the underlying soft tissues, as was maintained by Agassiz: they only do so at the margin of the scale, where the median layer is not yet developed; but towards the centre, where the median layer exists, these grooves do not pass through it. The ridges intervening between these radiating lines are of some thickness, and are transversely subdivided by a large number of small ridges. These ridges are really the concentric lines seen on the surfaces of most cycloid and ctenoid scales. The superior layer of the scale covers the entire surface of the scale even to its extreme periphery, but the median ceases to exist at some little distance from the margin. The growth of the superior layer is effected at its upper surface by the calcification of a thin superficial membrane which covers the scale at the same time that the corresponding though different process is adding to the lower surface of the median layer. He says "it thus becomes manifest that these concentric ridges are not lines of growth, as thought by M. Mandl, but the result of a peculiar arrangement of the superficial tissue of the scale, a conclusion which accords with that arrived at by M. Agassiz." After a description of the scales of the carp, pike, salmon, perch, he says, "The question which now suggests itself is, what relation does the superior investing membrane bear to the inferior fibrous portion?"

To this question, however, he is unable to give anything more than hypothetical answers (see page 654, Williamson) and continues, "Be the process of its genesis what it may, we have here demonstrative evidence of the existence of such a superficial film of soft membrane as is essential to my hypothesis, accounting for the peculiar structure and growth of the uppermost layer." He further regarded the substance of the superior layer as probably identical with the ganoin existing in Lepidosteus, Lepidotus, and their allies.

Leydig gives a description of the structure of scales,* in which his reference to the corpuscles of Mandl is the most important point raised. These are

* Leydig, 1851.

sometimes situated freely side by side, or the one above the other, sometimes they increase directly to form the asperities and teeth on the posterior border of scales (*Perca fluviatilis, Acerina cernua*), sometimes they fuse together at their margins, forming a united mass, a layer of the scale. Leydig asks of what nature these corpuscles are which on fusing come to produce scales. In considering the rôle of these corpuscles in the production of scales, he considers them as analogous to the free globules of Czermak, which on fusing together produce dentary substance.

According to him, the grooves on the scales of the lateral line show a different texture from the rest of the scales. They are rather true osseous products superadded to the scales. In another paper Leydig gives observations on the structure of scales in *Polypterus bichir*,* which does not specially deserve attention in a paper dealing mainly with cycloid scales. In a later work Leydig deals with the subject of the corpuscles in scales of various genera; † but this consists in the main of a reproduction of his previous work in the first paper mentioned.

Hollard issued a monograph on the family Balistidæ.‡ The disposition of tubercles and spines on the scales, their grouping and mode of formation, have chiefly engaged his attention so far as he takes up the subject of scales in this monograph. Hollard § published a second monograph on the Ostracions, in which he gave a detailed description of the tegumentary and scale systems in this family. He held that the spines on scales are of value for purposes of specific classification.

Steenstrup issued a paper in which there is an interesting note in direct connection with the main subject of my paper. ‖ He says, "The scales of osseus fishes, Cycloid, Ctenoid, and Ganoid, persist during the entire life of the fish. They grow with the growth of the animal. The scaly covering of fish is consequently composed of the same number of scales during the entire life of the animal. This is so true, that allied species may be distinguished with certainty by the number of scales in each longitudinal line." Steenstrup states that the case is very different in cartilaginous fishes, that placoid scales do not grow with the fish. Their size never exceeds certain limits, and their existence is only temporary. They fall off continually and give place to others.

Owen gives a brief note regarding the scales of the tunny, and a description accompanied by a figure of the scales of the eel. ¶

Blanchard published a work on the fresh-water fishes of France.** In this work he does not give any detailed description of the internal structure of scales, but he gives figures and descriptions of their external appearance for a number of species. He finds it difficult to agree with Agassiz's idea of the mode of scale growth by the successive addition of new plates or laminæ to the inferior face of previously existing ones, and in regarding the concentric lines as the edges of those plates, as, according to Blanchard, the number of concentric striæ is as great in very small as in very large fish of the same species. Blanchard brought forward a novel idea as to the function of scales, namely, that they fulfil a rôle in the respiratory function, varying in degree in

* Leydig, 1854. † Leydig, 1866. ‡ Hollard, 1853, 1854.
§ Hollard, 1857. ‖ Steenstrup, 1861. ¶ Owen, 1866.
** Blanchard, 1866.

different types, but notably developed in the Cyprinidæ, for example, in which the scales are penetrated by canals through which water may easily percolate.

We are indebted to Dr. Salbey for an interesting paper on the structure and mode of growth of fish scales.* In this work Dr. Salbey commences with some points on the structure of the skin, in which he reviews facts already known, then he gives a brief description of the four types of scales (Placoid, Ganoid, Ctenoid, and Cycloid) established by Agassiz, and lastly he deals with the external characters, internal structure, and mode of growth in the Cycloid and Ctentoid types. According to Salbey, there are two layers in scales, (1) an external or superior layer and (2) an internal or inferior layer. The superior layer develops at the expense of the superficial layer of the skin by the deposition of calcareous salts at the interior of this layer. The inferior layer is composed of superimposed lamellæ, indefinite in number. These lamellæ, are not homogeneous but are of two kinds. They are arranged in such a manner that a comparatively thin lamella is found between every two thicker lamellæ. These thin and thick lamellæ differ in character. The thick lamellæ are colourless and calcareous in their nature, the thin lamellæ are yellowish and composed of a conjunctive substance, a kind of cement (*Kittsubstanz*). Thus the arrangement of lamellæ is that of a conjunctive layer disposed between every two calcareous layers. In making sections the conjunctive layer resolves itself into fibrous elements, the individual elements of which appear to follow the same direction. The number of superimposed lamellæ has no definite relation to the age of the fish, as seen by a comparison of the number of lamellæ on fish of the same species, but of very different ages. He thinks, however, that as the lamellæ of older fish are thicker, and as the difference in colour between lamellæ does not appear, it is probable that conjunctive lamellæ calcify during progressing years and fuse with adjoining calcareous lamellæ. From this occurrence, it would result that the number of lamellæ, while really being greater in the older fish, does not appear to be so, on account of the lines of separation between the old lamellæ having disappeared. On the preceding characters Dr. Salbey builds the following interpretation of scale growth. In the membrane situated at the inferior part of the scale there takes place a periodic deposit of calcareous matter. This membrane, impregnated with calcareous salts, represents the inferior lamella of the scale. Between this calcified inferior lamella and the skin there appears a new layer of conjunctive substance. After a varying lapse of time, this new layer calcifies itself in its turn and so on. This mode of growth may serve to explain, says the author, how it comes about that the inferior layer of the scale is the largest, and why there is a softer layer present at the inferior part of the scale. This softer layer is merely a layer of conjunctive substance, which has been deposited upon the most inferior layer between that and the skin. Besides these facts relating to the layers of scales, Salbey deals with the concentric lines, the grooves, the focus, and corpuscles.

Concentric lines. The concentric lines have not any connection with the lamellæ which compose the scale, as one may easily show by vertical sections. These lines or ridges only belong to the superficial layer, and thus one under-

* Salbey, 1868.

stands how they may abruptly disappear, and how new striæ may interpose themselves between previously existing striæ.

The grooves. These represent channels carved out of the surface of the superior layer; and the conjunctive substance mentioned above constitutes their foundation. Besides the grooves directed from the periphery towards the centre of the scale, there exist in Ophidium and other fishes grooves concentrically arranged. "These varied grooves may contribute to the enlargement of the scale at the surface, and permit through the intermediation of the conjunctive substance, which calcifies slowly, a continued deposition of calcareous salts in the lamellæ, which are not in direct connection with the skin, and in the conjunctive substance of the scale."

The focus. Regarding the focus of the scale, Salbey agrees with Peters in rejecting Agassiz's idea as to its formation by a process of exfoliation or wearing down of the oldest layers of the scale. It is natural, he says, that the projections which are nearest the centre of the scale should be smaller and less apparent than those which are situated nearer the periphery, because at the central point, where the superior layer of the scale is thinnest, as it was formed at a period in the early life of the fish, the projections or crests would not be so distinct and pronounced as those in peripheral parts formed during the later life of the fish. The presence of skin at the surface of the scale does not allow of any other explanation, and in order to believe that a wearing down has there taken place, it is necessary to suppose that a destruction of the epidermis and of the skin has taken place at this part. The focus is nothing else than the oldest part of the scale. It is also the thickest part of the scale, because there we have the greatest number of lamellæ at the internal face of the scale.

Corpuscles. Salbey does not bring forward any important facts as to the corpuscles of scales. He agrees with Leydig in regarding them as ossified globular bodies.

Teeth. Regarding the teeth of scales, Salbey rebuffs the opinion of Peters, according to whom these parts develop from the corpuscles of scales. He also disagrees with Mandl, who regarded these appendages as true teeth. He considers these small teeth as integral parts of the superior layer. These minute teeth appear successively at the posterior border of the scale as that grows; it is because of this mode of growth that the points formed in the last part appear perfectly preserved, while those which during the progress of growth become carried further forward are very small and much broken by external friction.

Carpenter devotes several pages to the structure of scales in osseous, ganoid, and placoid fishes.* On the subject of osseous fishes, he deals in a very concise manner with the scales of the eel, carp, and sole.

Regarding the cycloid and ctenoid divisions established by Agassiz, he considers this sharp division as having little harmony with the general organisation of the types which it has the aim of separating.

Vaillant also takes up the question of the value of cycloid and ctenoid characters as propounded by Agassiz for purposes of classification.† He shows the great variation which occurs in the scales of Percidæ, not only in different

* Carpenter, 1868. † Vaillant, 1872.

individuals of the same species, but on different regions of the body on the same individual. Owing to this variation he regards Agassiz's division into cycloid and ctenoid as of little value.

The next work which I have to notice is a lengthened and interesting paper by Baudelot, in three parts.*

Part I. is concerned with a historical review of the literature relating to scales previous to the year 1873, of which I have made ample use in the foregoing pages. Part II. contains a detailed study of a certain number of types of scales, considered from the point of view of structure and development. Part III. has a number of facts on the value of the characters found in scales in relation to classification.

Part II. consists of two sections, of which the second section gives a synthetic summary of the facts propounded in the first section.

In Section I. he treats of the following:—

Analytical study of types of scales.

1. *Perca fluviatilis*, with eight figures.
2. *Phoxinus lævis*, with one figure.
3. *Esox lucius*, with two figures.
4. *Clupea harengus*, with one figure.
5. *Anguilla vulgaris*, with five figures.
6. *Ophidium barbatum*, with two figures.
7. *Gadus merlangus*.
8. *Cyprinus carpio*, with eight figures.
9. *Pleuronectes solea*, with five figures.
10. *Thynnus vulgaris*, with seven figures.
11. *Mugil capito*, with eleven figures.
12. Hypostomum, with fourteen figures.

In this analytical study of the foregoing types of scales, he devotes much attention to the corpuscles of scales.

In the second and synthetic section of Part II. he treats of the following:—

1. The connection between the scales and integument.
2. The form of scales and their mode of orientation.
3. The size of scales.
4. The ridges on scales.
5. The spines on scales.
6. The grooves on scales.
7. The perforating canals in scales.
8. The internal lacunæ of scales.
9. The focus or centre of growth.
10. The tissue of scales.
11. The formation and growth of scales.

1. *The connection between the scales and integument.* The scales of cycloid and ctenoid fishes are usually contained in small dermic sacs, and are more or less visible to the exterior; but in some cases they are not so, being deeply buried in the skin (Anguilla, Ophidium, Lota, etc.).

* Baudelot, 1873.

When scales are provided with spines, as in Ctenoids, the points of these may be seen piercing the epidermis, and so appearing freely at the surface. The degree with which scales adhere to the skin is subject to great variation in different fish. In the herring, for instance, scales are very easily detached; but in *Dactylopterus volitans*, etc., they are only separated from the skin with much difficulty. Scales are never entirely free in the dermic pouch, as they are always connected with its walls by fibrils of connected tissue, usually of extreme fineness. In imbricated scales the free portion has a more or less intimate connection with the skin, and so in extracting scales from the body of the fish, the free portion carries with it débris of the skin, from which it is frequently difficult to separate it. In certain varieties of carp (mirror carp, leather carp), in which, as one knows, scales may disappear on more or less extended parts of the body, the scales show very varied connections with the skin. On certain parts one meets with very large scales much imbricated, on other parts the scales are still larger, but scarcely covered over, or even entirely isolated. Extremely small scales are also found, which are completely enclosed in the depths of the skin. The imbrication of scales ought to be considered so far as a phenomenon of mechanical arrangement intimately connected with the greater or lesser development of scales and with the degree of their separation.

2. *The form of scales and their mode of orientation.* The form of scales is extremely variable. These variations occur not only in different species, but in different regions of the body of the same fish. In each fish the large scales covering the median region of the flank may be considered typical, that is to say, they possess in the largest measure and with most constancy all the proper characters of the species. Scales from the dorsal and ventral surface, from the head and fins, frequently show more or less marked deformations, and seem to lose some of their characteristic features. Scales oval at one place may change into a circular form at another place, polygonal scales to circular ones, elliptical to a more or less irregular form.

Lobes at the margins of scales, spines, concentric ridges, and grooves may vary considerably in number, and even disappear altogether in different parts of the body. "Nothing is more variable than the external characters of scales, and as in a tree one does not find two leaves exactly identical, so is it in regard to the scales of fishes; but the particular features of scales, as of leaves, do not all vary at the same time, and thus there generally remain several general characters of resemblance which scarcely allow us to confound the scales of one species with those of another." The simultaneous presence of cycloid and ctenoid scales was pointed out by Baudelot in the following:—*Trigla lineata*, *Sargus Rondeletti*, *Perca fluviatilis*, *Pleuronectes solea*, *Pleuronectes flesus*, etc.

The form of scales appears somewhat to depend upon their connection with one another, their juxtaposition; thus scales isolated in the skin tend to have a rounded or circular form (Lota, Anguilla, Ophidium). On the contrary, where scales are large and much pressed the one against the other, they most frequently take a polygonal form. The orientation of the long axes of scales in relation to the axis of the body is usually fairly constant in those fish in which there is a regular and distinct imbrication of scales. In fishes in which the scales are isolated and completely enclosed in the skin (Anguilla, *Ophidium barbatum*, etc.) the long axis of the scale does not usually show any fixed position as regards its direction.

It appears probable that the reciprocal pressure exercised by scales the one upon the other, contributes so far in bringing about a similar mode of orientation among them.

3. *The size of scales.* The size of scales is extremely variable. They even show varying dimensions on different parts of the body of the same fish. For instance, the scales on the flanks are larger than those near the caudal fins. Scales gradually diminish in size from the median region of the side towards the tail or anus. Scales are also reduced in size in various parts of the head, in the opercular and preopercular regions and in the suborbital region. Baudelot gives tables showing the variation in size in different regions of the body for the perch, pike, and mullet. These tables show in what proportions the size of scales varies with the age and size of the fish mentioned. Growth is continuous but unequal in scales from different regions of the body. One finds very great variation in the size of scales in different species of the same family of fish, and certain varieties of the same species show extreme differences in the relative sizes of their scales. For example, the so-called mirror carp has very much larger scales than those of the ordinary carp. In another variety, the leather carp, the scales have become very rudimentary or have entirely disappeared.

4. *The ridges on scales* (crêtes de l'écaille). In cycloid and ctenoid fishes the surfaces of the scales show linear projections which are usually parallel to the external contour of the scale. Baudelot describes the arrangement of these under the term "crêtes de l'écaille." Though these ridges are almost constantly present, yet in several types of fishes they disappear more or less completely, for example, in *Dactylopterus volitans* and the tunny. In the tunny one finds some scales provided with as many ridges as usual, others with ridges only at the margins, and others in which these ridges are completely wanting. In the eel, scales do not show ordinary ridges on their surfaces; these are replaced by reliefs of a quite distinct appearance, but really of the same nature as the ridges.

In regard to the disposition of ridges on the scale surface there is considerable variation in different fishes. In certain types of scales, those of the salmon for example, the ridges run parallel to the contour of the scale in a perfectly regular manner, thus forming a series of continuous reliefs which may truly be termed "concentric ridges." In other types of scales, those of the pike, some Cyprinidæ and Pleuronectidæ, for example, the concentric ridges show some degree of regularity in the peripheral portion of the scale, but as they approach the centre of growth they lose their uniformity, become interrupted at various points, bent in various directions, intersected by secondary ridges, and finally appear like a "veritable labyrinth." In regard to this point there are the greatest differences between scales of the same fish.

In many scales the characters of the concentric ridges undergo a greater or less change in the posterior region of the field; sometimes they may entirely disappear (herring, shad), sometimes they become very rare, they separate the one from the other, lose their regularity, enlarge at certain points, or become covered by tubercular projections (carp and other Cyprinids).

In some fishes these ridges assume a peculiar mode of orientation. Instead of following a course parallel to the contour of the scale, they take a direction more or less perpendicular to this line, remaining, however, parallel to one another (Alepocephalus, herring, shad). The particular disposition observed in the herring, etc., is not an isolated fact, but the expression of a more or less general fact which appears in various degrees. The number of concentric ridges is not the same in the different regions of the scale. It is usually much greater in the anterior than in the lateral field, and in the lateral than in the posterior field (perch, pike, minnow); this fact helps to prove that all the ridges do not originate round the circumference of the scale. The number of ridges may show the greatest variations in scales of the same fish; the number appears to be in proportion to the extent of the scale. Thus in large scales from the flanks the ridges are relatively numerous, in very small and rudimentary scales from other regions of the body (caudal fin, opercular region) these ridges are extremely reduced in number. "*Variations in the number of ridges are not usually great in scales from the same region. In fishes of the same species, but of different age, the number of ridges increases proportionately with age, and consequently also with the dimensions of scales." It is easy to verify this fact by comparing scales from the same region in fish of very different size.*

From this point of view, Baudelot made observations on scales of the pike, perch, and minnow to determine the differences in number from simple to double, triple, quadruple, and so onwards.

New ridges are formed successively at a very slight distance from the border of the scale by a partial calcification of the external layer. This calcification shows itself firstly as a simple track of calcareous molecules in the membranous zone which exists at the margin of the scale. This track of molecules represents a calcigenous centre round which the calcareous substance accumulates.

From the thickening of this calcareous track there results firstly a slight projecting part, which in raising itself soon constitutes a ridge. This enlarges little by little at its base by the addition of calcareous molecules and finally unites with adjoining ridges, so as to form a continuous calcareous investment on the surface of the scale. This mode of formation of ridges may be easily followed in the scales of the sole, in the membranous zone which constitutes the border of each of the lateral fields; and it is also obvious in the scales of many other types of fishes.

The ridges of the scale surface examined under a very high power show their free borders to be sometimes smooth, but in other cases crenated in such a manner as to present fine denticulations. These denticulations may be seen in the scales of the mullet, perch, and burbot, but the asperities are not uniformly present on all the ridges of the same scale, and they may be completely absent in the marginal ridges. In many scales (burbot, mullet) the concentric ridges appear to offer a marked inclination towards the centre of the scale. This inclination shows itself by a more or less pronounced difference in the degree of obliquity of the two planes corresponding to the two opposed faces of the concentric ridge. Tranverse sections, that is to say, sections perpendicular to the surface of the scale, also show this point. The separation of the ridges is not great, and does not appear to vary with age; the latter point evidently proves that the scale does not grow at all points on its surface. The distance separating the ridges from one another may remain the same in the different regions of the scale; but this is by no means constantly the case. In the sole, for example, the ridges are much closer in the anterior than in the lateral part of the scale; and in most cycloid scales the ridges of the posterior region show a greater degree of separation than those of the lateral and anterior regions (minnow, Cyprinus, etc.).

"*It is also not uncommon to find in the same area of the scale successive zones in the extent of which the ridges show different degrees of separation.*" (See figures of carp scales.)

From the following facts, Baudelot concludes that the ridges do not represent by any means the borders of superimposed plates or lamellæ, as many zoologists had supposed; but that these ridges, whether they be concentric lines or not, are nothing else than reliefs corresponding to lines of calcification at the external layer of the scale.

(1) The ridges only very rarely affect a complete arrangement in the form of concentric lines.

(2) These ridges may be perpendicular to the contour of the scale.

(3) These ridges may show the most irregular arrangement, become folded up against one another, entangled in all directions, or even form a sort of network of irregular meshes.

(4) The ridges are appendages to the superficial layer of the scale.

(5) They originate at the margin of the scale as points of isolated calcification.

(6) They show a marked inclination towards the centre of the scale.

5. *The spines* (spinula). Under this heading Baudelot discusses the small spinous projections seen in the posterior portion of ctenoid scales. The variation in the form of those appendages is very great, affording transitions from simple denticulations to true teeth. In the tunny, for example, we find quite simple denticulations or cuttings in the posterior border of the scale which cannot be regarded as distinct organs, but simply as projecting lobes of the free border of the scale. At a further stage (some species of Sargus) denticulations project from the concentric ridges of the posterior field. This is really only a more marked phase of the microscopic denticulations already mentioned in connection with the concentric ridges. In a still further developed stage the spines cover the entire surface of the posterior field, and are conical, pointed, or truncated. Notable variations of this form are seen in different fishes; for instance, in the mullet the spines are plates, with the external surface raised in slightly projecting cones; but on the other hand, in the perch the spines are much elongated, and appear as true spines much tapered at their extremities.

In a fourth case, as in the sole and some other Pleuronectids, the spines are long, rounded, and drawn out at their extremities as in the last case; but they are not solid, but hollowed out internally into a more or less spacious cavity. In the fifth degree, the spines have the same external form as in the last case; but they are not composed of homogeneous tissue similar to that of the scale, but of dentine, in which canaliculi extend from the central canal to near the surface. Such a structure is found, for example, in the spine of Hypostoma. As to the dimensions of spines on scales and their growth, he says that in passing from the free border to the centre of the scale they gradually lose their volume, but in a transitional manner. The dimensions of spines increase with the age of the fish in a marked degree. The number of spines also varies in different regions of the body and with age. By a comparison of scales from the same fish one finds that the number of spines varies only slightly in points from the same or adjoining regions of the body; but those scales from different regions show considerable variations as to the number of spines. There are, however, exceptions to this rule (dab). The number of spines as of concentric ridges is usually greatest in scales from the median region of the side.

In those regions in which scales tend to be rudimentary, they also tend to lose their spines, and thus become cycloid. The fact seems almost certain, that there does not appear to be a single ctenoid fish in which one would not meet cycloid scales on certain points of its body. Baudelot brings forward some facts to show that new spines form themselves behind those already existing on the posterior border. The spines and concentric ridges are homologous productions, and growth of both takes place in the same direction. According to Baudelot, then, spines are products of the same nature as the concentric ridges; they are ridges which have become very prominent, and cut into transversely in such a manner as to constitute a series of prolonged spines, each with a distinct base. In support of this hypothesis he brings forward the following facts:—

In many scales, such as those of the perch and mullet, the edge of the concentric ridges presents a series of very distinct microscopic indentations, and in some ctenoid scales the spines are so small as to represent only stronger indentations of the ridges of the posterior region which have become very prominent. In many cycloid scales, such as those of the carp, the posterior region shows a series of tubercles arranged with as much regularity as spines, and which present the greatest analogy to these structures. These tubercles are, however, only partial thickenings of concentric ridges. In the same fish scales become altered and pass from the ctenoid to the cycloid condition, and in that case it frequently happens that the spines become replaced by simple ridges, a substitution which is a clear proof of the homology of spines and concentric ridges. Among Pleuronectidæ, in which some are ctenoid (sole, dab), and others are cycloid (brill, flounder), the scales of cycloid forms frequently show in the posterior area, instead of rows of spines, distinct islets of calcareous matter, each supporting a fragment of concentric ridge. When these islets of calcareous matter become straitened and more regular, they evidently result in spines.

6. *The grooves* (sillons) *on scales.* This term has been given to very narrow grooves or trenches which are supposed to have been excavated at the expense of the superficial layer of the scale. These grooves are not present in

all scales; those of the salmon and lote, for example, do not possess them. They may be limited to one region of the scale, or be present over the entire surface. From a general point of view, they may be divided into two categories:—(1) Those which radiate from the centre of growth towards the periphery are termed *radial or radiating grooves* (carp, perch). (2) Those which have a direction parallel to the contour of the scale, and therefore perpendicular to the radiating canals, are termed *transverse or concentric grooves* (Ophidium, whiting). Those two kinds (*radiating and concentric grooves*) may be present simultaneously in the same scale; but in the majority of scales only the *radiating or radial grooves* are found. In most cases they only occupy the anterior region of the scale (perch, pike), but they may occupy the posterior as well as the anterior areas (carp), or they may be present over the entire surface of the scale, anterior, posterior, and lateral (loach, minnow, whiting). When the concentric grooves and radiating grooves are present in the same scale, two cases present themselves: firstly, that in which the two kinds of grooves are found in two different areas of the scale (several Pleuronectids), in which case the radiating grooves exist in the anterior and posterior area, and the concentric or transverse grooves in the lateral areas; or secondly, that in which the radiating and concentric grooves exist in the same area of the scale, by which means *the scale surface is divided up into numerous plates or divisions, which occasionally form a regular series of plates radiating from the centre to the periphery* (Ophidium, whiting, eel).

While in a general way one may separate the grooves into these two categories, namely, radiating and transverse grooves, there are many scales in which the grooves lose their usual symmetry and affect a more or less irregular arrangement. Sometimes the grooves show up to a certain point the usual radiating arrangement and then anastomose with each other, thus forming on the scale surface a species of plexus of irregular webs (Labridæ, Mormyridæ). The grooves of the anterior area also frequently anastomose with those of the posterior area in the region of the centre of growth (Cyprinus, Labrus). In the herring and shad there are grooves in the anterior part of the scale which originate on the lateral border, and extend across the anterior area, keeping more or less parallel with one another.

As regards form, the grooves show extremely varied characters: sometimes they take the form of a simple line, resembling a fissure or line of break on the external surface of the scale (herring, shad, transverse grooves of Ophidium, whiting); sometimes they appear as a species of ravine, narrowed at the base and cut out perpendicularly at the sides; at other times they have the appearance of a wide trench of little depth and flat at the base; sometimes the grooves lose their regularity, become narrowed at some points and enlarged at others, constituting species of small depressions (*lacules*) with sinuous and irregular contours; sometimes a groove may be interrupted at certain places, and then one has a series of small cavities or depressions (*lacules*) lying in the same straight line and in the same direction. The edges of grooves are usually irregular and jagged, but they also frequently show rounded lobes, due to the presence of calcareous globules.

The radiating grooves do not usually extend over the entire distance from the border of the scale to the centre of growth; a certain number of them do extend over all this distance, but the others usually only run over a portion of the radius. Some of the radiating grooves commence at the periphery and stop almost immediately, others extend a little further, and others still further without reaching the centre of growth. Ridges may also be seen commencing at only a short distance from the margin of the scale, sometimes terminating at the centre of the scale, and at other times terminating after a short passage. It is clear that there occur grooves whose course is reduced, as they only extend over a minimum portion of the radius. Grooves occupying the median portion of the anterior area are, as a rule, longer than those at the sides or lateral areas of the scale. This also holds true for the grooves in the posterior region of the scale. When the radiating grooves are wide, regular, and very close together, the scale surface appears as if it had been cut into a series of bands or triangular tongues, with the apices turned towards the centre of growth (see anterior region of scale of sole).

The concentric or transverse grooves are situated between the concentric ridges, and are more or less parallel to them. These grooves are, as a rule, only found on a limited part of the scale surface, and they occur more frequently in the periphery than in the part surrounding the centre of growth. These concentric grooves may be very narrow (whiting, Ophidium) or very wide (lateral areas in various Pleuronectids). When very wide concentric grooves co-exist with radiating grooves equally wide, the surface of the scale becomes divided up into calcareous areas of varying size. These areas may be irregular (posterior area of various Pleuronectids, scales of *Gadus molva*), or they may be regularly rounded and in the form of small medallions (scales of eel). The number of radiating grooves varies much in different scales from the same fish; these variations become very apparent in comparing scales from different regions of the body, rudimentary with well-developed scales. In extremely rudimentary scales grooves may not exist. In scales from the same region of the body the number of radiating grooves does not vary to nearly the same extent. The number of grooves of an individual scale is capable of varying with age. As regards the transverse or concentric grooves, there does not appear to be any doubt that these grooves, which are situated between the concentric crests, are formed at the same time as the latter. In regard to the radiating grooves, it appears that they multiply during the growth of the scale, at least in a very large number of cases.

If the number of grooves in scales increases with age, it may also become reduced. This fact appears true for the transverse grooves, as in scales in which these grooves are found (whiting, Ophidium) one usually finds them much more pronounced towards the periphery than towards the centre, where they may completely disappear. As to reduction in the number of radiating grooves, Mandl observed that they disappeared in old fish belonging to the genus Abramis, and in other old scales they evidently disappear in the area round the centre of growth. Baudelot remarks that "up to the present time (1873) the grooves on scales have not been explained in a satisfactory manner." Mandl regarded them as canals serving for purposes of nutrition of the scale; Peters as suture lines which rendered possible the growth of scales. Williamson held that they were erosions effected at the expense of the superior layer of the scale. Vogt thought the radiating lines as difficult to explain in young as in adult scales, and Blanchard regarded them as canals which had connection with the supposed respiratory function of scales. Dr. Salbey thought that they were excavations of the superior layer aiding the growth of the scale in surface extent. It appeared necessary to Baudelot to abandon all these interpretations of the grooves on scales. From his observations he held the following view: "The grooves of scales ought to be considered as lines or zones of non-calcification, that is to say, as lines to the level of which the calcification of the exterior layer of the scale has not taken place." The exterior layer has centres of calcification which later unite with each other as these centres extend. "When the union of the centres of calcification takes place from the centre of growth towards the periphery and occurs at the same time in the transverse direction, that is to say, parallel to the external contour of the scale, there result radiating grooves; when, on the contrary, the union of calcigenous centres takes place parallel to the contour of the scale, without having taken place at the same time in the radial direction, transverse or concentric grooves result. When the union of calcigenous centres fails to take place both in the radial direction and transversal direction (parallel to the external contour of the scale) at the same time, there results the simultaneous existence of radiating and concentric grooves. Lastly, when the union of calcigenous centres takes place without order and symmetry, the surface of the scale shows grooves arranged in a more or less irregular manner. It is hardly necessary to add that when the union of centres of calcification takes place completely in all directions, there is no further trace of grooves at the surface of the scale."

7. *The perforating canaliculi.* Under this term Baudelot described for the first time extremely small canals which traverse the scale through and through from the upper to the under side. Baudelot firstly observed these perforating canaliculi in the carp; but found them later in many other fish scales, both cycloid and ctenoid. These perforating canaliculi are only found in the posterior area of the scale. In some types of scales they are easily observed, in others only with difficulty. In the scales of the carp the perforating canaliculi open externally in connection with the radiating canals of the posterior area, and traverse the scale through to the under side in a slightly oblique direction, and terminate internally on the inferior surface of the scale. This internal opening or ostiole is usually nearer the posterior border than the external ostiole, and further, if one takes a line down the middle of the scale, one finds that the internal ostiole is further from this axis than the external ostiole. In *Mugil cephalus* the canaliculi round the centre of growth present certain peculiarities which are noteworthy. They traverse the scale more obliquely, and have a larger diameter. At the external surface these canaliculi open into grooves or trenches and pass on towards the large canal, which in Mugil occupies the centre of each scale. The grooves in connection therewith anastomose with each other, and gradually enlarge as they approach the median canal, where they terminate by bending into a spout-like or canalicular orifice. The large canal in the centre of the scale should be considered as a species of collector in connection with the nearest adjacent canaliculi.

As to the mode of formation of these canaliculi, Baudelot remarks that he has not a sufficiently large number of facts to give a satisfactory answer to this question. He says, however, that where radiating canals exist, the canaliculi form themselves on their course, at their free extremities on the posterior border of the scale. At the extremity of the radiating groove there firstly appears a small depression; later by the mode of growth of the surrounding tissue this depression deepens more and more, and finally closes in at the posterior end, forming an aperture like a minute pierced gap across the lamina of the scale, which is very thin at this point. As the scale increases by the addition of new layers to its internal face, each gap become gradually converted into a narrow canal, in which the length varies with the thickness of the scale and with the distance of the canaliculi from the posterior border.

As to the nature and function of the perforating canaliculi, Baudelot throws out certain hints. He believes that the canaliculi give passage to a filamentous cord, which is either of the nature of connective tissue or a nerve-fibre. He is inclined to believe that it is of the latter nature, and if this is true, that there might be grounds for establishing a connection between the perforating canaliculi and the canals which traverse the scales of the lateral line. The scales of the lateral line receive nerve-fibres on their deep surface, and in their interior nervous structures have been demonstrated.

In Mugil, in all those scales showing similar passages to those of the lateral line, a certain number of perforating canaliculi anastomose with the median canal of each scale.

In the pike, many of the scales have a similar trench to those of the lateral-line scales. This trench, hollowed out at first, may be considered as analogous to the depressions which represent the first stage in the formation of the perforating canaliculi. In a sparoid fish showing a disjointed and equitant lateral line he found a scale which showed at its centre of growth a duct which penetrated obliquely from the internal to the external face of the scale. This duct, while much narrower than the median canal of the lateral line, was at the same time very much larger than the perforating canaliculi of adjoining parts, that is to say, a kind of transition between the two kinds of canals. From the preceding facts, which he throws out in passing, Baudelot thinks that if they are confirmed by later researches, a clear resemblance between scales of the lateral line and other scales would become apparent. This would also explain why in certain types all scales or a large number of them may revert to the characteristic features of scales from the lateral line.

8. *The internal lacunæ of scales.* Certain scales possess lacunæ developed in their interior. In *Holocentrum longipenne*, for example, some of the perforating canaliculi show lateral diverticula which spread out horizontally in the scale substance. These diverticula constitute a system of lacunæ. In the scales of Hypostoma internal lacunæ are well developed, and constitute a vast system of anastomosing canals, in which the cavity communicates with those of the spines. In *Dactylopterus volitans* the scales are hollowed out in their central portions by large irregular lacunæ which communicate with each other. In the tunny the scales present remarkable lacunæ. In this case these lacunæ, which occupy all the median portion of the scale, form a species

of spongy tissue, limited at each side, namely, on the external and internal faces, by a thin plate of compact tissue. As to the mode of development of these lacunæ, Baudelot admits the absence of all knowledge; but he thinks that the "presence of these lacunæ in the tissue of certain scales establishes a clear analogy between the structure of these productions and that of osseous tissue." The lacunæ of the scales of the tunny and of Dactylopterus, for example, resemble very completely the lacunæ seen in the ossified connective tissue of the rays in the fins of various fishes (Gasterosteus, etc.). Ramifying lacunæ, such as are found in the scales of Holocentrum, can be observed with exactly similar characters in the operculum and suboperculum of the same fish, and as in the scales, the lacunæ of the opercular bones communicate with the exterior by ducts analogous to the perforating canaliculi. "These facts seem to show that the phylogeny of scales and that of osseous tissue should be associated."

9. *The focus or centre of growth.* Under this term one understands that more or less central part of the scale around which growth first takes place. In the rigorous meaning of the word the focus ought to be represented by a point which corresponds to the exact spot of origin of the scale; but in using this term zoologists have given this word a wider meaning, namely, that region of the scale in which formation first takes place in the life of the fish, and which is characterised by the absence of or irregularity of the concentric ridges. In some scales the focus is smooth or only very slightly roughened; in others its surface is marked by projecting calcareous reliefs, granulations, or tubercles, either laid down in lines or without any definite order; in others, again, ridges analogous to concentric ridges occur, which by their indefinite arrangement form an inextricable network, or a network of irregular meshes. The focus, as a rule, shows no grooves; but in some cases the radiating grooves are prolonged to the focus, sometimes retaining their original characters, sometimes, however, becoming interrupted from point to point, and thus forming small superficial lacunæ which are not disposed in any regular order. When these grooves reach the centre of growth (focus) they frequently anastomose with those of the opposed border. It is frequently difficult to define the precise limits of the focus, owing to the fact that an insensible transition is effected to the surrounding parts. The dimensions of the focus, however, show very great variations, not only in scales of different types of fish, but in scales from the same fish.

In the perch, minnow, and pike, Baudelot has shown how the dimensions of the focus may vary in the scales of the same fish: by the side of scales in which the focus is almost nil, one may meet with others in which the focus attains the size of one-half to two-thirds the total diameter of the scale. This fact alone is sufficient to demonstrate that the size of the focus is not proportioned to that of the scale. Some scales possess a very large focus, those of Labrus and Crenilabrus for example; others, on the contrary, possess a very small focus. The position of the focus in relation to the centre of the scale is very variable from one type to another. In some fish the focus occupies nearly the centre of the scale; this is the case, for example, in the lote, minnow, and eel; this fact appears more especially true when scales are small, rounded and concealed in the depths of the skin. In the majority of scales the focus is carried backwards a greater or less distance from the centre of the scale, for example, in the perch, sole, brill, carp. In some cases the focus has been carried so far backwards that it is situated at the posterior border of the scales, as in several species of gobies. It is much more rare to find the focus carried forward from the centre of the figure; this is met with in the scales of the tench (*Cyprinus tinca*). Baudelot states that the scale increases at its periphery, and that there is not any true growth at the focus by intussusception; but only a process of simple repair, which may modify the configuration of the calcareous reliefs or cause their disappearance by transforming, for example, a surface primitively covered with regular concentric ridges into a granular surface with tubercles or with vermiform ridges.

Agassiz and Vogt regarded the focus as the result of the wearing down of the central portion of the scale. Peters successfully refuted this interpretation by observing that the frictional or wearing-down process could not take place owing to the fact that the scales are contained in pouches of the dermis, which would protect them. In order to explain the existence of the focus, Baudelot points out that scales frequently show zones with irregular ridges alternating with zones with normal and regular concentric ridges, and he concludes that the cause which produces this regularity or irregularity of the disposition of the ridges is itself very unstable, and he holds that it is some such cause which produces the focal region; in short, this hypothesis supposes a change in the mode of distribution of reliefs during successive epochs of the life. Baudelot held, however, that he had not a sufficient number of facts either to confirm or negative this hypothesis, and left the matter in abeyance.

10. *The tissues of scales.* Scales are composed of two substances: (1) *fundamental organic substance;* (2) *inorganic substance.* The fundamental organic substance belongs to the group of connective tissues (dermal); the inorganic substance consists of calcareous concretions of phosphate and carbonate of lime. The fundamental organic substance is more or less transparent and homogeneous in appearance, and is readily broken up into folia which are composed of elementary fibrils. By dissection or through the action of reagents, such as soda or potash, it is easy to separate the component folia of scales from one another. These folia are extremely thin, are superimposed the one upon the other like the leaves of a book, which become smaller as they approach the external face of the scale. The scale is more or less like a cone with a large base, and in which plates or folia are piled the one on the top of the other from base to summit. These folia separate from one another most readily in the median portion of the scale, but not so readily at the periphery, at which region, indeed, they adhere to one another so intimately that it becomes difficult to isolate them without tearing them and getting fragments of several adjoining folia. Isolated folia are somewhat transparent, flexible, and membranous. They are not entirely homogeneous, as with a high power they show in their thickness a fine striated appearance. At the periphery of the lamellæ, where rents have been made, the tissue shows itself decomposed into fibrils or into bundles of fibrous tissue. The striæ of adjoining lamellæ do not follow the same direction, but cross at angles to one another. At the

focus the striæ of adjacent folia cross each other usually at right angles; but this is not the case at the periphery, where they cross at very varied angles, sometimes forming vortices in which it is difficult to follow the direction of the striæ.

The inorganic substance of scales consists of corpuscles of carbonate and phosphate of lime scattered in the depths of the folia of the organic fundamental substance.

There has been much difference of opinion as to the distribution of these calcareous corpuscles. Mandl maintained that the corpuscles were contained in a special tissue situated above the inferior surface of the scale. Agassiz held that these corpuscles are lodged near the superior and inferior surfaces of the scale. Peters believed that the corpuscles are found on the inferior surface of the scale, but never on the superior surface, as Agassiz had maintained. Williamson made use of sections, and was the first to recognise the presence of corpuscles in the entire thickness of the scale.

Baudelot agreed with Williamson in the main points, and after an analysis of the scale, layer by layer, enunciated the following more detailed points:—

"(1) In the most internal folia of scales the corpuscles are few in number or entirely absent.

"(2) In the folia following the most internal the corpuscles become rapidly very numerous, and their number increases as one proceeds from the internal to the external surface of the scale.

"(3) Near the external surface of the scale, the corpuscles are so numerous that they form a sort of compact web in the thickness of the fundamental organic substance.

"(4) The external calcareous investment of scales is simply a conglomeration of fused calcareous corpuscles."

In other words, calcification of the folia of scales is more advanced as one approaches the external surface of the scale, and this one can readily understand, as it is on the internal surface that the formation of new tissue takes place. In each of the more internal folia of the scale calcification is more pronounced towards the periphery than in the focal region. In the focal region the corpuscles are less numerous, usually isolated and separated from one another by spaces completely deprived of calcareous deposits. Towards the periphery of the folia, on the other hand, the corpuscles are very abundant and become massed together throughout the fundamental substance. In the most *external* folia of the scale, in which the calcification is much more advanced, the corpuscles are seen to be numerous throughout the entire extent of the folia.

The corpuscles are not of the same volume at all points of the same lamella. In the focal region they are relatively large; but as one proceeds from the focus to the periphery they gradually diminish in size until they become of extreme delicacy. The volume of the corpuscles is not the same in the various folia of the scale; thus in the most recent and internal folia the corpuscles, where they exist, are usually much smaller than in the more external folia. The size of corpuscles seems to vary with the age of the scale; for example, in the scale of a young fish the largest corpuscles are much smaller as compared with the largest corpuscles of a scale from an older fish.

The long axis of corpuscles does not present a uniform direction throughout the extent of the scale. The direction of the long axis generally agrees with the direction of the fibres of the folia to which the corpuscle belongs. It has already been noticed that fibres of consecutive folia of the scale cross one another frequently at right angles, and the same thing has taken place for the corpuscles which belong to these folia. Corpuscles of one, two, or several consecutive folia frequently become fused together. Corpuscles represent products of a crystalline nature, and exhibit a series of concentric lines which succeed one another from the centre to the periphery. This is not true for all corpuscles, as some have the appearance of vitreous substances, are perfectly homogeneous, and show no trace of concentric lines.

Baudelot concludes from his observations that the corpuscles are crystalline deposits effected in the tissues of the scales, and more or less modified by this tissue. They are of the same nature as the artificial products, studied firstly by Rainey* and then by Harting.†

11. *The formation and growth of scales.* Scales only appear subsequently to hatching, sometimes a long time after this has taken place; for example, in young eels measuring 7–8 centimetres in length they have not yet appeared. The scale originates as a spot of dermal calcification, which extends little by little, and thus comes to constitute a small solid lamella, which represents the primitive scale. The first lamella, once formed, sometimes remains closely united to the surrounding tissue, sometimes acquires a certain mobility; but this mobility is never complete, and the scale always retains intimate connections with the dermis by its internal surface and by its margins, and the external surface itself frequently shows adhesions at the free margin. The young scale grows by the addition of new layers of increasing size, which add themselves successively to its internal face. This mode of growth explains how it is that the scale is considerably thicker towards the centre, and much thinner and less calcified at the periphery. At the internal surface of the scale, and at its margins, tracts of connective tissue are found, by means of which the scale adheres to the pouch in which it is contained; but at the external border, on the other hand, the line of demarcation between scale and dermal pouch becomes more and more marked. As to the subsequent progress of calcification, one can establish that it extends from the exterior towards the interior, and from the periphery of the scale towards the centre. In each layer the calcification is more complete on the border than in the central portion. These calcifications unite with each other, and constitute the calcareous crust of the scale surface.

As to the concentric ridges and spines, these appear successively on the borders of the scale as that gradually extends itself. One has to admit that

* "On the mode of formation of the shells of animals, of bone, and of several other structures, by a process of molecular coalescence, demonstrable in certain artificially formed products." Rainey, 1858.

† Harting, "Further Experiments and Observations." *Quart. Journal of Microscop. Science*, n.s., vol. i. (1861) p. 23.

all ctenoid scales are cycloid at the beginning of their formation. Growth does not take place equally in all scales of the same fish, as one may observe scales of different sizes in different parts of the body. Although scales, as a rule, form themselves by the successive addition of new layers to their internal surface, there are some scales, such as those of the tunny and *Dactylopterus volitans*, which present difficulties. These scales show internally a spongy tissue, hollowed out into lacunæ of varying size. The structure of these scales affords, according to Baudelot, a connecting link between the tissue of scales and osseus tissue with internal lacunæ, such as one observes in the opercular skeleton of various fishes (Gasterosteus).

In the third part of his monograph, Baudelot takes up the question of "scales considered from the point of view of classification." He considers this question in relation to the following points:—(1) Connection of scales with the integument. (2) The form of scales. (3) The dimensions of scales. (4) The presence or absence of scales. (5) The ridges on scales. (6) The spines on scales. (7) The grooves on scales. (8) The perforating canaliculi and interior lacunæ of scales. (9) The focus of scales. (10) The tissue of scales. In summarising the results derived from a consideration of these points, he concludes that none of these characters of scales taken by themselves can serve as a basis for the classification of fishes, that the most important of all of them, the cycloid and ctenoid character, does not possess the degree of importance which many zoologists have attached to it, and that the other characters noticed are of still less value. Although each character by itself is of little value, yet the characters of scales as a whole ought not to be neglected in establishing natural groups. He recognises that in order to put such a programme into execution a much more precise knowledge is necessary of the external characters, structure, and mode of development of scales in a large number of types of fishes. In this connection he refers to Steeg's paper as a useful essay on scales from the point of view of classification.*

The next paper which I must notice is that by Ryder on the mechanical genesis of the scales of fishes.† He says in his introduction "that fourteen years previously he had suggested that the slow metamorphosis of the forms of the crowns of the teeth in man, in the course of a vast number of successive generations, might be ascribed to the continuous, slow, and cumulative action of mechanical strains and pressures in definite directions, resulting in the production of permanent stresses and consequent changes in the forms of the crowns, especially of the molar series. . . . The present paper is an attempt to apply somewhat analogous reasoning to a somewhat simpler, but no less interesting problem in morphogenesis." Scales take their origin from a continuous subepidermal matrix, a basement membrane. This basement membrane is thickest on the dorsal and lateral aspects of the body, as seen in sections of the young, for example, in *Batrachus tau*, a scaleless form. It is "seen in larval stages of scale bearing forms, and may be continuous with a very thin basal membrane from which the primordial fin-rays of embryo fishes seem to be partly differentiated. . . . Such a matrix appears to be co-extensive with the entire epidermic layer of the young in many types of fishes, just at the time when the scale commences to be developed."

* Steeg, 1857. † Ryder, 1892.

Ryder's hypothesis seeks to account for the arrangement of scales in longitudinal and oblique rows in two directions, and for their state of imbrication. Scales are arranged in oblique rows showing two directions: (1) a direction from above downward and backward; (2) in the reverse direction, from below upward and backward. The scales may thus be enumerated in three different directions: (1) in a downward and forward direction; (2) in a downward and backward direction; and (3) starting from any scale in any oblique row, they may be counted either forward or backward longitudinally in the direction of the long axis of the fish. In archaic types, the number of scales in a longitudinal row on the sides of the body corresponds very exactly with the number of muscle-plates or somites of the body. The myocommata, or sheets of connective tissue intervening between the successive muscle-plates are attached with great firmness to the deeper layers of the skin or corium. The structural arrangements at the time of scale development noted above, affect and modify the subsequent growth of the scale matrix. During the swimming movements of the fish the entire integument is thrown into definitely circumscribed areolæ, the central portions of which remain in a passive condition, while the periphery is wrinkled and folded as a result of the action of the lateral muscles of the fish. In this way each and every one of the dermal and epidermal areolæ are circumscribed by the action of the fish in the normal act of swimming. In each of the circumscribed areolæ a scale develops; the continuity of its development with its fellows across the margins of the areolæ is prevented by the continual bendings or flexures to which the dermis is there subjected owing to the action of the muscles. As it is impossible to state clearly the details of Ryder's paper without also giving his drawings, I will content myself with quoting several of his sentences.

"It will be clear that in the case considered the arrangement and imbrication of the body is determined by the actions of the segmentally arranged muscles of the body. In other words, whatever has determined the development of somites has also, in the most clear and direct manner, determined the segmentally recurrent and peculiar trilinear and imbricated arrangement of the scales of many fishes. It may be urged that heredity has determined the number, arrangement, and the development of the somites, and therefore the development of the scale is also a sequence of hereditary influences working thus indirectly. This view of the case may be admitted without invalidating the conclusion that given the growing mechanism here described, the development of the scale would, under any circumstances, have been interfered with at the parts where the integument was being continually flexed, wrinkled, or folded, as it is around the integumentary areolæ wherein the scales are formed, as has been here proved to correspond with the facts."

Ryder summaries "two conclusions of prime importance:—

"(1) The scales of fish bear a segmental relation to the remaining hard and soft parts, and are either repeated consecutively and in oblique rows corresponding to the number of segments, or they may be repeated in rows as multiples of the somites, or segmental reduction may occur which may effect the arrangement of the scales so as to reduce the number of rows below the number of somites indicated by the other soft and hard parts.

"(2) The peculiar manner of interdigitation of the muscular somites as indicated by the sigmoid outline of the myocommata, as seen from their outer faces, and the oblique direction of the membranes separating the muscular cones, has developed a mode of insertion of the myocommata upon the corium which has thrown the integument into rhombic areolæ during muscular contraction. These areolæ are in line in three directions, and the folds separating them, particularly at their posterior borders, are inflected in such a manner by muscular tensions, due to the arrangement of muscular cones, as to induce the condition of imbrication so characteristic of the squamation of many fishes."

The next paper which I must notice is a very important one by Dr. Klaatsch.* While acknowledging my indebtedness to and appreciation of this lengthened paper, I must at the same time agree with Ussow (see p. 202) in regarding some portions of Dr. Klaatsch's work, for example, the section on the "Structure of the teleostean scale from the histogenetic standpoint," as wanting in complete clearness.

The teleostean scale, its arrangement and position in the skin. The scales of Teleosteans are represented by more or less circular plates of hard substance, which exhibit considerable variation in their form. This variation is, however, insignificant in comparison with the general agreement which typical teleostean scales show with one another. Klaatsch chooses the cycloid scale as representative of the ordinary teleostean scale, not only because it presents simple conditions, but because it supplies a suitable object for placing the skin-covering of Teleosteans in line with that of Selachians and Ganoids. As examples of such scales, one may think of such as those of the salmon or of Esox. One distinguishes in such scales two layers: (1) *an outer homogeneous layer* and (2) *an inner fibrillar layer*. Each scale is in its anterior half arranged with regard to others in an imbricated fashion, namely, the anterior half of each is covered by three scales, one of which is anterior and dorsal to it, a second anterior and ventral, and a third directly anterior. The centrum of the scale is usually covered over, and scales surround the body in oblique rows.

For the arrangement of scales in the skin, he gives a figure and description of a transverse section through the skin of a young specimen of *Cobitis fossilis*.

Under the epidermis, which contains a large number of mucus cells, the dermis is seen to be raised in a series of projections, each of which corresponds with the posterior free end of a scale. Each scale lies in an oblique direction from behind forwards, and becomes enclosed in a compartment of the dermis, the so-called "scale pocket." In this scale pocket one distinguishes an outer and an inner wall. The outer wall consists in its posterior part of loose connective tissue containing numerous chromatophores; in the anterior part the outer wall is composed of tense connective tissue, which is similar to the inner wall of the adjoining anterior scale pocket.

The fibrous projections of this connective tissue of the outer wall of the scale pocket unite themselves at the anterior border of the scale with the deepest layer of the dermis, in which the fibres have a course parallel to the surface of the body. The inner wall of the scale pocket in its posterior part unites with the outer wall of the adjoining posterior pocket. Further forwards it is

* Klaatsch, 1890.

built up of the fibrous processes of the deep dermis layer. Near the scale its condition changes, as immediately towards the inside of the same, numerous cells are found in a ground substance only slightly developed and not fibrillated. The fibres of the deep dermis layer have a similar arrangement to that of Ganoids and Selachians.

One may easily ascertain this by observing a piece of skin from the surface. The fibres of one layer of fibrous bundles cross those of the next higher or deeper layer in such a way that, in relation to the long axis of the fish, the anterior and posterior angles of intersection are greater than right angles. The fibres surround the body in a diagonal direction to the body axis, corresponding to the rows of scales. Towards the musculature the dermis is bordered by a layer of cells which resemble the other cells of the dermis, but lie closer to one another. In this part chromatophores are also seen. Underneath the dermis the musculature only shows young fibres similar to those seen in immature forms. As regards number, the scales have nothing at all to do with the myocommata. Several scales are usually found on a myocomma; the relation to metamery suggested by Salbey does not exist.

The development of the teleostean scale has hitherto not been worked out; one only finds a few incomplete references to this subject. The first who takes any notice of the subject is C. Vogt, in his "Embryologie des Salmones," who mentions "poches épitheliennes," in which the scales are formed. According to him, these pockets are simply folds of the epidermal membrane. This point will be referred to further on.

Later Leydig devoted some attention to the structure of scales, but did not concern himself with their ontogeny. He says, "The scales of most of our fresh-water fishes appear partly as ossifications of flattened skin continuations which one generally terms scale pockets." He regards scales as fusion products, "peculiarly developed calcareous globules, concretions, or scale corpuscles," such as one finds on the lower side of scales in many Teleosteans.

Baudelot held the same view as that of Leydig. Although Baudelot's work appeared in 1873, he does not make any note as to the part which cells take in scale formation; "according to him, the scale is simply a conglomerate of calcareous concretions or scale corpuscles, with whose measurements he fills many pages of an extensive treatise."

Development of scales in the trout. Klaatsch followed the development of cycloid scales mainly in the trout; but he also made use of Esox and several Cyprinoids for some of the earliest stages. The following are the results of his investigations:—

In the trout the first formation of scales appears several months after hatching. Trout 2 cm. in length show no scales, but somewhat older ones show the commencement of scale formation. Scales firstly originate in the anterior and median region of the trunk near the lateral line, and their formation extends from this region caudalwards, as well as ventrally and dorsally.

For this reason trout 3 cm. in length are suitable specimens for the study of scale formation, since older and younger stages occur near one another, the younger being more posterior. Before scale formation commences, the skin of a trout shows a thin epidermis and relatively very fine dermis. In the just hatched trout, the dermis is represented as a homogeneous layer of little consistency. Within this lies a cellular layer resembling epithelium. This epithelial layer is that described by Hatschek as the "bordering epithelium of the dermis."

At the stage in which the first foundation of the scale appears the skin is about ·03 mm. thick. Of that thickness the epidermis occupies about one-half, and consists of four to five layers of cells, of which the most external layer is somewhat flattened. In the remaining part of the epidermis the cells are somewhat cubical and show the presence of nuclei. Mucus cells with sickel-shaped compressed nuclei are also seen, and a thin basal membrane separates the epidermis from the dermis. The outer surface of the epidermis is smooth.

The dermis consists of a small number of lamellæ lying horizontally upon one another. So long as there is no trace of scales, the lamellæ in the dermis extend nearly to the epidermis. The dermis cells, which as in earlier stages lie in small numbers between its lamellæ, show somewhat flattened nuclei. The cells become rather more numerous immediately beneath the basal membrane of the epidermis, and the nuclei here are slightly more circular in form than those of the other dermis cells. Chromatophores are also seen at this part; but of blood-vessels there is no trace in the dermis. Chromatophores are also to be seen situated above the bordering epithelium of the dermis. Internally to this last follows the musculature, the most external portion of which is made up of only young stages of muscle-fibres. The first foundation of the scale appears as an aggregate of dermis cells lying beneath the basal membrane of the epidermis; but neither the basal membrane nor the epidermis itself takes any part in the formation of the scale. The cells which gather together to form the scale foundation are distinguished from the other cells of the dermis in possessing larger nuclei and a better-developed protoplasmic body. This cell-mass, the foundation of the scale, resembles epithelial tissue. Each scale germ presses upward on the basal membrane of the epidermis as a slightly arched papilla. During this upward growth of the scale germ the upper surface of the epidermis remains smooth; but at the places where a scale germ is situated the epidermis is reduced from five to two or three layers of cells. In transverse section the scale germs are seen as papillæ, whose highest points are not exactly at the centres of the masses of cells, but are situated slightly caudalwards. These cell-masses (scale germs), which approach the circular form in surface view, stand free from one another in regular rows, diagonal to the body axis. Later the entire cell-mass spreads itself out horizontally, and its elements arrange themselves in two slightly flattened layers. Between those two layers there appears *a thin layer of strongly refractive substance.* In transverse section it is seen that the formative cells lay down the new substance, alternately on the outside and on the inside, producing what looks like a slightly undulated plate. The form of the plate is approximately circular, corresponding to the form of the cell-mass. These plates can be isolated and represent small scales. The strongly refractive substance later on shows itself to be the hard substance of the scale: at what period this plate impregnates itself with lime salts Klaatsch has not investigated. The formative cells which give rise to the scale are known as *scleroblasts,* and they correspond to similar elements in Selachians and Ganoids. At this period the minute scales appear as circular discs, which lie adjacent to one another in regular order; but they do not as yet show any special covering. The scales so far lie parallel to the upper surface of the body, and do not project nearly so strongly into the epidermis as they do later; but at the posterior end of each scale the epidermis projects inwards, as can be seen in tranverse sections. In the strips of skin intervening between the scales, cells of the dermis lie embedded in great numbers in a ground substance consisting of a few irregularly arranged fibrillæ.

Above the anterior end of the scale several elements penetrate between the basal membrane of the epidermis and the scale, adding themselves to the scleroblasts already present there, and resembling the scleroblasts in their appearance. An increase of the dermis cells internally to the scales also takes place. As the scale was originally enveloped symmetrically on all sides by formative cells, a change in the distribution of scleroblasts is the more noteworthy. On the upper or more external surface of the scale they lie closer to one another than on the lower or more internal surface; but they lie particularly close to one another at the posterior part of the scale. As the latter portion of the scale is specially active in growth, the highest point of the scale germ becomes displaced entirely in the caudal direction. The slight inward invagination of the under surface of the epidermis, continued here from previous stages, becomes gradually considerably enlarged; but the epidermis by this infolding gains as little as previously any part in scale formation. Contemporaneously all layers of the skin grow in thickness, and the epidermis comes thereby to consist of a large number of layers of cells. In the dermis also that part situated between the lamellæ and the scales undergoes a great degree of cell proliferation. The scale comes thereby to lie on a layer of loose connective tissue, by which it is separated from the deeper part of the dermis, in which the ground substance had already undergone a lamellar differentiation. At the same time there takes place an increase of dermis cells between the epidermis and the scales, and new elements thus become added to the scleroblasts on the upper surface of the scales, while the uppermost or most external layers of the dermis separate scales and scleroblasts from the epidermis. The scales thus become enveloped on all sides by loose connective tissue, from which the scleroblasts receive new auxiliaries. The posterior end of the scale shows as yet no connective tissue covering. The result of this mode of growth is that the scale always inserts itself deeper in the epidermis. The scales, along with their envelopes of connective tissue, have the appearance of papillæ which press the epidermis before them in an oblique direction caudalwards. The epidermis during this process does not become uneven on the external surface, but, on the other hand, is thrown into folds on the internal surface. Klaatsch regards these folds as equivalent to the "epithelial pockets" described by C. Vogt. A section shows the corresponding epidermic processes running out pointed in front and extending far underneath the posterior border of each scale. The position of the scale in the skin now undergoes an important change. The posterior border of the scale becomes pressed against the upper surface, and the anterior end expanding underneath the epidermic continuations, becomes sunk towards the interior. From the original horizontal position the scale passes into a position oblique to the upper surface. The consequence of this change of position is that the scale, not being hindered by adjoining structures, can increase the extent of its surface in an oblique direction. A necessary result of further growth is that scales push themselves under adjoining anterior scales by their anterior borders, so that they begin to cover one another like tiles. In order to understand further changes it is necessary to bear in mind that all layers of the skin increase continuously in thickness. The deep lamellar layer of the dermis takes, in antithesis to early stages, a stronger growth, and in this development it is the outer layer next the scales which undergoes a change. The epidermis also grows, as well as the continuations of the same underneath the posterior part of each scale. In this inward growth of the epidermis no tissue change takes place; for instance, one finds in these continuations similar mucus cells to those in the rest of the epidermis. This growth of the epidermic continuations is not to be regarded as a process proceeding from the upper skin alone, but as the result of growth taking place in the entire skin. In this connection the constant increase of the scale at its posterior border is of significance. The anterior border of the scale inserts itself always deeper in the loose connective tissue of the dermis, whose stronger development towards the upper half of the deep dermis has already been noticed. It therefore happens that the scale does not lie next to the deep dermis; but it gives rise to an appearance as if the scales had pushed themselves between the lamellæ. This takes place because the loose connective tissue underneath the scale gradually becomes differentiated in a similar manner to that which had taken place earlier in the deeper part of the dermis, and in this case also lamellar fibrillated bundles are formed. These lamellæ do not, however, lie parallel to the surface of the body, but parallel to the scale. The lamellæ form themselves in the same manner as the scales, growing stronger towards the anterior part; the dermis layer situated between the scales becomes so arranged that connective tissue septa exist between the scales. These septa, which are the inner walls of the scale pocket, are connected externally with the epidermic continuations, and internally they grade imperceptibly into the deep layer of the dermis. By the foregoing means the scale pockets come into complete formation. These scale pockets appear consequently as a result of scale growth. In this two different processes operate together: on the one hand the scale becomes separated from the epidermis by growing connective tissue, and so an outer wall to the pocket is formed in its anterior part; on the other hand the floor of the pocket and the posterior part of its outer wall is formed by the ingrowth of the scale into the loose portion of the dermis and by the development of the same. The floor of the scale pocket is of special significance in the development of the scale. The tissue of the dermis which produced the floor of the scale pocket retains immediately underneath the scale its indifferent state. Here there lie cells in a ground substance which is not yet broken up into fibrillæ. When the same prove themselves active as scale formers, they lead to the formation of a deep scale layer, which shows in its histological relationship much peculiarity. A superficial view of the latest stages shows how the scales gradually insert themselves underneath the three next anterior, until we arrive at the condition found in older fish. The median point of the scale becomes distinctly prominent by the formation of concentric ridges. It remains uncovered for a considerable time, until it also becomes overlaid by the posterior border of the next anterior adjacent formations.

Structure of teleostean scales from the histogenetic standpoint. The dermis cells which take part in scale formation are large elements with well-developed nuclei, each of which shows a distinct nuclear membrane, and also, as a rule, a large nucleolus. These cells lie at first so close to one another that they mutually affect one another in shape. From a circular form they pass over into a polygonal one. While the cells on the internal surface of the scale become disconnected from one another on the first separation of scale substance, different cell layers come into formation on the external surface. Above the deepest scleroblasts immediately overlying the young scale a layer of cells extends which easily allows itself to be lifted up *in continuo.* At the margins of the scale the original condition persists, as here the cells of the outer as well as the inner surface unite themselves into an almost complete covering for the scale substance.

The superficial scleroblast layer presents a very characteristic structure. Its polygonal-shaped elements simulate a flat epithelium. Between the protoplasmic parts, which stain deeply in carmine or hæmatoxylin, there exists a network which does not stain. This network appears like a system of intercellular spaces, and there is nothing so far to prove that the clear strips between the cells are an intercellular substance. The further changes of these cells clear up the meaning of the intervening substance. The cells undergo a process of change which seems to take place for all in a similar manner. Each cell extends itself in one direction, which is not quite determined in relation to the entire scale. It attains thereby a lengthened form, and the nucleus comes to have a more peripheral situation in the cell. The nuclei of adjoining cells during this process come to lie nearer one another. In all the cells a part containing the nucleus becomes distinct from a part in which there is no nucleus. In the latter part the protoplasm loses at one place its power of taking on stains, and in this part there appears a clear circular spot which resembles a nucleus in size and general form. There is no internal structure in this clear spot, which afterwards expands in the direction of that part of the cell farthest from the nucleus, and finally unites with the clear network between the cells.

The different stages correspond with a process of cell-metamorphosis: the clear strips between the cells, owe their origin like the clear spots in the cells above described, to a substance which has become differentiated from the rest of the protoplasm.

This substance unites with that part of the scale already existing. The nucleus and a part of the protoplasm are preserved. The substance derived from the cells is thus a secretory product. Klaatsch says, "An dem vorliegenden Objekte, welches für die Untersuchung des scleroblastischen Processes in Flächenbilde sich vortrefflich eignet, konnte ich nichts wahrnehmen, was zu Gunsten der Annahme spräche, dass Zellen *in toto* in das Produkt aufgingen; die Kerne zeigten keine Veränderung, ich sehe daher in der Bildung der Hartsubstanz einen Abscheidungsprocess." This product, the substance of the scale, is thus an intercellular substance hardened by the deposit of lime salts, and the described cell layer is simply a layer of scleroblasts, which are only distinguished by regularity of arrangement and by sharp marking of individual stages of the scleroblastic processes from the deeper cells of a similar kind with which they are continuously dependent at their borders. The nearer the scleroblasts are towards the margin the more do they show (though here no longer separable into layers) an increase of their cell-body in a tangential and a decrease in the radial direction in relation to the entire scale. As in other Physostomi, ridges are formed on the external surface of the scales of the trout. These ridges have a concentric arrangement on the scales of this fish, which is not, however, a general rule for superficial reliefs. In the trout the cells concerned arrange themselves so that they correspond exactly with the concentric ridges. One might expect that the superficial scleroblast layer would cover the deeper cell layer with its product, so that the constituent parts of the last would be taken up into the interior of the scale substance. This does not, however, take place in the trout. The cells arrange themselves as they pass through the changes described, so that they come to lie on the external surface of the ridges and contribute to the enlargement of these. They elaborate, as it were, the upper relief surface of the scale, for which the deeper cells had only supplied the foundation.

In the older stages and in the mature condition of all the scleroblasts there remain only the nuclei and small masses of protoplasm. One sees the cells lying on the surface of the scale; if one takes a scale from a living fish, for example from one of the Cyprinoids, and observes it in a fixing fluid, say chromic acid, then one easily recognises circular nuclei surrounded by protoplasmic masses which extend in fine continuations. A similar condition to that in the trout appears in other Teleosteans; in many Clupeoids, for example in *Elops saurus, Albula conorhynchus,* cells are found perfectly similar in their arrangement to those in the trout and surrounded by scale substance; these represent true osseous cells adjoining the concentric ridges. In other forms there are numerous osseous cells present in the scales.

In Osteoglossum, for example, the wealth of bony cells, and in consequence the thickness of the cell-containing layer, is very apparent. In this form a true cell-containing osseous tissue constitutes an essential part of the scale; in the trout scale, so far as it has hitherto been observed, a similar tissue must be recognised. Its scleroblasts are osteoblasts; whether these become enclosed by their product or not is of subordinate significance, as in related forms sometimes the one, sometimes the other is the case.

Originally the outer and the inner surfaces of the scale are alike in regard to their scleroblasts. On the inner surface, however, the scleroblastic processes gradually take another direction. As the outer and inner scleroblasts gradually pass into one another at the margin of the scale, and as both originate from the same cell material, no sharp separation can be drawn between them.

The scales retain for a lengthened period of their ontogeny the structure of a thin bony plate, whose growth takes place especially at the margins and at the external surface. Not until the time when the scales have reached the condition of being a tile-like covering does a considerable increase of volume commence on the inner surface. The scale has here received, by the formation of a scale pocket, a connective tissue foundation. It appears that this lower layer gradually differentiates itself so that it becomes similar to the deep lamellar dermis layer, but that close to the scale a layer of cells persists, which continues in an indifferent condition, in so far as the tissue surrounding it still shows no fibrillar structure. This cell material on the floor of the scale pocket becomes a matrix for the so-called lower scale layer. In its fibrillar structure and the lamellar layering of the fibrillæ the lower scale layer agrees with the dermis tissue; by the total absence of cells it differs from that tissue. We cannot, however, assume from the first factor that the lower scale layer owes its origin to a development of connective tissue fibrils, for this is contradicted by the second factor and by the genesis of the layer. If previously differentiated dermis tissue of the scale pocket were included directly in the substance of the scale, there must exist a connection between scale and scale pocket in order that both of these may pass directly the one into the other. Secondly, the cells already occurring in the dermis tissue must be found again in the interior of the scale after the inclusion of the tissue in the interior of the scale. Neither of these occurs; in the interior of the lower scale layer there is no trace of cells or cell remains, and the scale is separated from the dermis tissue by an indifferent zone.

From the previous histogenetic facts one gains the following ideas as to the histological structure of scales:—

The outer layer consists of bony tissue. This layer is homogeneous and is deficient in any special structure, except for a slight lamellar layering (see, for example, Williamson, 1851, plate xxviii., fig. 9, of the Carp). The chemical composition consists of amorphous phosphate of lime and carbonate of lime. The formative cells of this layer are situated chiefly on the upper surface. They represent that which Williamson has described as a membrane, on which the growth of the layer depends. The scleroblasts form the superficial relief of scales. If they become enclosed in their own secretory product, then bone corpuscles are found in a great variety of conditions as regards number and arrangement. On the addition of hydrochloric acid the entire layer dissolves, but somewhat slowly. There is no difference in reaction with this acid between a piece of fish bone from the internal skeleton and the external scale layer; both develop at first rapidly and then more slowly carbon di-oxide.

The lower scale layer consists of fibres united into bundles, the fibres all running parallel within the bundles. The bundles of one layer again lie fairly parallel to one another, and cross those of the next higher and deeper layers at acute angles. There are usually three different systems to be distinguished in a scale, which cut one another at similar angles. This tissue agrees with tense connective tissue, and especially with that of the deep dermis layer. Consequently it appears right, as most authors do, to regard the lower scale layer as the connective-tissue part of the scale, yet no one has placed the peculiarities of this tissue in a clear light. This should be done in two directions: firstly, in regard to the adjoining connective tissue of the scale pocket; secondly, in regard to the external scale layer. As regards the first point, development has taught that the lower scale layer does not represent pre-existing connective tissue of the scale pocket which has become annexed to the scale. In regard to the deeper-situated connective tissue, this questionable layer must be defined as tense connective tissue without cells, whose formative cells probably originated from the connective tissue of the scale pocket. "The development of this peculiar tissue can only be fully understood by taking into consideration phylogenetic factors extending far backwards. Its peculiarity may, however, be partly explained by reference to the development of the entire dermis. As Hatschek has shown, and as I also find in the trout, the dermis consists originally of a layer, the formative cells of which lie only on the inner side. The formation of the fibrillar structure of the layer is independent of cells, which only arrive later in its interior. The dermis cells return likewise to an embryonic stage in the course of scale formation, and it is conceivable that events which govern the formation of the entire dermis repeat themselves in detail."

Regarding the relation of the lower to the upper layer, it is of significance that the upper layer exists for a long time alone, and that it is not till later, when the covering of the scale has completed itself, that the other part of the scale first appears. There exists indeed a genetic relationship between both layers, and the external bony layer has indeed occasioned the formation of the second. But now as it is a matter not simply of a connective-tissue lower layer of the original scale, but of an integral portion of the entire structure, it follows that a sharp separation between both layers is as little tenable as a separation between the formative cells of both surfaces. At the margins of the scale the layers cohere intimately with one another. As the lower layer becomes impregnated with calcareous salts, a closer coherency is by that means given to both layers.

This impregnation with calcareous salts never takes place in the lower layer to the same extent as in the upper layer; the substance remains little capable of resistance against alkalies; but Klaatsch believes that a sclerotic-like formation takes place, though in lesser degree. The calcareous concretions which Mandl has described thus appear in the lower layer. They are ovoid, layered bodies which are largest in the centre of the scale. Immediately beneath the outer layer they lie so thick and congregate so intimately together that Williamson has made a special third layer out of that part. Leydig referred to them as "Kalkkugeln." He overrated their significance in scale formation. "Now they again gain significance, but in another sense to that which the earlier authors thought. These formations appear as the lower scale layer gradually becomes changed by a sclerotic-like formation. The scale represents a plate, which consists of an outer and an inner layer. The outer is bony tissue, the inner owes its origin to connective tissue, 'das in den Sclerosirungsprocess einbezogen worden ist; sie besteht aus theilweise sclerosirten Bindegewebslamellen, zwischen denen keine Zellen liegen.'"

In a later paper Klaatsch* returns to the question of the development of the teleostean scale, and comes to the conclusion that it follows the same course as that of the bones of the head, which he now describes. He points out that his former work requires correction as regards the origin of the elements which form the scale. The scleroblasts in reality arise from the

* Klaatsch, 1894.

ectoderm, and not from the connective-tissue layers. Those beneath the scale (the lower scale layer) are budded off from the ectodermal invagination, which grows in under the posterior end of the scale.

To Ussow we are indebted for a paper on the development of the cycloid scale of Teleosteans.* This author differs in a number of points from Klaatsch's views on the same subject. I shall endeavour to give a summary of Ussow's paper.

The scale of Teleosteans is built up of two layers, the structure of which is not agreed upon by the various authorities. Hofer, for instance, considers the *first and outermost layer of the scale* to be composed of a form of dentine which he terms "*hyalodentine*," and speaks of the transformation of this special tissue into common dentine. *The second and innermost layer* of the scale is, according to Hofer, formed from the dermis.

Klaatsch, from the presence of minute osseus bodies in the first layer of the scale, holds that this layer is built of ordinary bony tissue. He believes that the second layer of the scale is formed out of connective tissue which is developed from the scale pocket.

Leydig and Baudelot regarded the scales of Teleosteans simply as a conglomeration of calcareous concretions or little scale bodies.

In regard to literature dealing with the development of scales, Ussow cites the following three papers:—

(1) Klaatsch, "Zur Morphologie der Fischschuppen and zur Geschichte der Hartsubstanzgewebe."

(2) Hofer, "Ueber den Bau und die Entwicklung der Cycloid und Ctenoid schuppen." *Berl. Gesellschaft für Morphologie und Physiologie in München.* 1889.

(3) Maria Sacchi, "Sulla struttura del tegumento negli embryoni et avanotti del Salmo lacustris." *Red. del Inst. Lombardo*, vol. xx. Milano. 1887.

The species which Ussow selected for the study of scale development were the following:—In the family Cobitidæ, *Cobitis tænia*, *Cobitis barbatula*, *Cobitis fossilis;* in the family Cyprinidæ, *Leucaspius delineatus*, *Leuciscus rutilus*, *Carassius vulgaris.*

As the origin and development of teleostan scales takes place from the mesoderm elements of the dermis, Ussow first gives some notes on the epidermis and dermis of *Cobitis tænia* as an example. In young examples of *Cobitis tænia* the skin is imperfectly developed and the epidermis is thicker than the dermis. In such young stages (embryos 4 cm. long) mucus cells are present in the epidermis in great number. The dermis consists at this stage of numerous fibres and cells embedded in an intermediate ground substance. In older forms the epidermis becomes much thicker and the mucus cells increase in number. The dermis also becomes thicker at the expense of connective-tissue fibres which cross under one another almost at right angles; these fibres, surrounding the body of the animal, lay themselves down in diagonal lines in relation to its longitudinal axis. The dermis is separated from the muscles by an epithelial layer of cells, not clearly marked

* Ussow, 1897.

out in all, which Hatschek termed the "*marginal epithelium of the cutis.*" According to some authors, the dermis is separated from the epidermis by a thin membrane, a distinct and independent structure, sometimes termed the ground membrane. Toldt, in his "*Lehrbuch der Gewebelehre,*" however, says, "It has now been almost generally accepted, not as an independent structure, but as a modification and thickening of the upper layer of the connective tissue ground substance." Ussow thinks that this membrane as an independent structure does not occur in the families Cobitidæ and Cyprinidæ, but simply that a transition substance of connective tissue devoid of fibres lies between the epidermis and the dermis.

The first stage in the development of a scale consists of fairly distinct and prominent aggregations of mesoderm elements in the upper half of the dermis, immediately beneath the epidermis. The cells forming such a papilla, as we may call these aggregations, differ at least in the beginning from the other cells of the dermis, and no ground substance is developed between them. This papilla gradually grows out in a horizontal direction, pushing the epidermis before it slightly upwards. When the papilla has reached a certain stage, a change takes place in its constituent cells. All cells excepting the lower become more circular in form and their nuclei gradually become more transparent; the lower cells, on the contrary, are, as before, highly coloured and their nuclei are spindle-shaped. In the next stage a *separation of the elements of the papilla into two layers, an upper and under, becomes distinctly observed. Between these two layers a thin strip of highly refractive substance stands out prominently.* At the commencement this strip does not extend throughout the entire length of the papilla, and one may see, in sections, that it is thickest at the centre, and gradually thins out towards its border, until at the end of the section of the papilla the strip is not visible.

The secretion of this refractive substance thus does not commence with the peripheral elements, but with the cells found towards the centre of the papilla. In further development, the substance of the first layer of the scale shows itself throughout the entire length of the section of the papilla, and the strips also become broader; meanwhile the papilla grows out in a horizontal direction. In this way a round curved plate originates, lying parallel to the upper surface of the body of the fish close beneath the epidermis. The upper and lower surfaces of this plate are formed out of scleroblast cells (the formative cells of the scales). The upper layer of scleroblasts simulates in its appearance a flat epithelium with clear spaces between its component cells. Later, each of the constituent cells changes, its nucleus comes to lie towards one end, and a circular colourless space appears at the opposite end. Klaatsch held that the clear spots within the cells fuse with the clear spaces between the cells; but Ussow did not observe any such fusion in his preparations. Klaatsch's description of these processes does not appear at all clear to Ussow. Klaatsch says that the cell structure on the external surface of the scale shows differentiation into several layers of cells, and that these cells build up the substance of the first layer of the scales. The question would naturally arise, how it is that the cells of the lower row do not become covered by the product of the upper cells. It would seem that the lower cells would become quite changed by the product secreted on them; but according to Klaatsch this does not take place, for he says, "An dem vorliegenden Objecte, welcher für die Untersuchung der scleroblastischen Processes in Flächenbilde sich vortrefflich eignet, konnte ich nichts wahrnehmen, was zu Gunsten der Annahme spräche, dass Zellen *in toto* in das Product aufgingen; die Kerne zeigten keine Veränderung, ich sehe daher in der Bildung der Hartsubstanz einen Abscheidungsprocess." In regard to the above, Ussow reiterates, "Alles das ist mir ganz unklar."

According to Ussow, the further development of the first layer of the scale takes place in the following manner:—

The cells overlying the substance of the first layer of the scale already secreted appear to waste themselves down more rapidly than the lower cells from the product secreted by them, so in the following stages one frequently sees a transparent strip of homogeneous substance in the position of the future scale; underneath this transparent strip and immediately united with it lies a row of scleroblasts with easily observable nuclei; on the upper side of the clear strips, on the contrary, one only sees three or four cells, the size of whose nuclei as compared with those of the lower scleroblasts is distinctly smaller. In still later stages one only meets with one or two such nuclei, and those much smaller than the nuclei of the lower scleroblasts. In section-cutting also it is easily seen that the overlying nuclei readily become loosened from the clear strips of the first layer of the scale, while, on the contrary, those elements lying beneath the clear strips form part of the latter, and never loosen themselves from it. In following stages the size of the underlying scleroblasts decreases, and at length there only remain, as in the case of the overlying cells, long extended, closely adjacent nuclei without trace of plasma, on which the first layer of the scale is formed.

Summary of preceding development.

(1) The cells of the papilla arrange themselves in two layers, the upper and under; between these two layers there appears a thin strip of refractive substance, the substance of the first layer of the future scale.

(2) The cells of the upper layer (the over-lying scleroblasts) use themselves up in the formation of scale material (its first layer) more rapidly than those of the under layer (the underlying scleroblasts); in consequence of this, one gets the stage of a plate with cells of the lower layer apparently enclosed therein.

(3) The first layer of the scale is apparently the product of the scleroblasts, that is to say, it is due to the change of the plasma of the latter into dentine-like substance.

About this time, when the first layer of the scale is quite complete, the change of its position in the dermis commences. Its posterior end (that turned towards the tail of the animal) raises itself gradually and presses on the epidermis; the anterior end, on the contrary, becomes sunk in the deeper layers of the dermis. This change in the position of the scale comes about through *the formation of the so-called "scale pockets."* Between the plates of scale substance there exist free portions of the dermis which lie close on the epidermis in these intervening spaces, and contain small aggregations of ordinary connective-tissue cells. By degrees the number and size of the cells increases, and there arise between them thin connective-tissue fibrils. Sections seem to show, without any doubt, that these fibrils of connective tissue in the scale pocket are directly formed at the expense of cells of the dermis, and are their immediate elongation. The developing connective tissue of this intervening part grows, as it were, between the epidermis and the anterior end of the scale, the horizontal position of the last gradually changing into an oblique position; the posterior end of the scale cuts into the epidermis, and envelops itself in this as in an envelope. The large development of connective tissue, the formation of the scale pocket, is thus the cause of the change in the position of the scale from a horizontal to an oblique position. The connective-tissue pocket itself appears as a newly developed connective-tissue layer, which lies between every two scales, the layer surrounding the scale on all sides (at least on the lower two-thirds). Owing to their oblique position in the skin of the fish, the scales can extend themselves in all directions without hindering one another in their growth.

When the first layer of the scale and the beginning of the connective-tissue pocket have already been formed, a layer of transparent, quite homogeneous substance appears at the border of the dermis underneath the scale; this layer contains pear-shaped nuclei, which increase very rapidly during the development of this layer; nucleoli are, as a rule, not observed. Klaatsch regarded this layer simply as cells of the dermis. According to Ussow, however, they are the lower elements of the papilla still remaining behind; during the entire development of the first layer of the scale they retained the characteristic spindle-shaped form of the basal elements of the papilla; but at this time they commence to increase in size and number, and between them a transparent intervening substance comes into appearance; further, one finds in longitudinal sections that this developing second layer enters into close connection with the first layer.

In this second layer one also finds nuclei which are plainly distinguishable by their size and pear-shaped form. No striation, no fibrils, are at first to be seen in the layer. At a later stage, however, we find a scale, which now consists of two distinct layers, the upper already known as the hyalodentin layer, and the lower without cells, but with fine striæ parallel to the upper surface of the scale. How does this striation originate? From what are those longitudinal fibres of the second layer formed? Klaatsch says the following: "In order to understand the structure of the second layer of the scale, one must know the formation of the entire dermis." According to Klaatsch, the dermis at the commencement of development consists of a layer on whose inner side lie the formative cells. The breaking down of the dermis into fibrillæ does not depend on those cells, which only penetrate into it much later. In the development of scales, the process which took place in the development of the entire dermis repeats itself, but in lesser degree. But the possibility of a direct appearance in the scale of the dermis of the connective-tissue pocket, already differentiated into fibrils, Klaatsch denies: he asks, "Where then do the connective-tissue cells disappear, for one finds no cells in the second layer of the scale (in the trout)." Ussow says, "I think my preparations show fairly clearly that the second layer develops itself anew, and is not merely a part of the connective tissue of the scale pocket. As concerns H. Klaatsch's explanation, it is not at all clear to me, because the development of the dermis is also not clear." H. Klaatsch says that threads arise in the dermis without any participation of its cells; but literature seems not wholly to confirm this view, as we read, "Die Fäden aus Zellen entstehen, indem sie aus dem Plasma der letzteren hervorwachsen (Ranvier)." Ussow then proceeds to note the varying opinions of different authorities in regard to the origin of the fibrils of connective tissue, and he concludes his remarks on this subject with the following sentence:—

"*Eine genauere Vorstellung von dem histogenetischen Vorgange der Fibrillenbildung auf Grund direkter Beobachtung zu geben, ist nun freilich schwierig und wir sind nach wie vor auf mehr speculative Erörterungen angewiesen.*"

In his preparations, Ussow sees something quite different to that described by Klaatsch. According to Ussow, the first phase of development of the second layer of the scale begins with a great numerical increase of the mesoderm elements underlying the first layer of the scale, then a transparent intermediate substance appears between them, firstly in a small degree, then always more and more, by which process the cells now become quite sunk in the intermediate substance. Ussow points out that in one of his figures (6u) one sees the dermis developing, which consists of cells embedded in a ground substance, and that this figure much resembles the figure showing the development of the second layer of the scale. He regards it as possible, as Klaatsch did, that in the development of the dermis these cells pass later towards the margins of the ground substance, and that the breaking up of the dermis into fibrillæ does not depend on these cells. But he asks if one can conclude either from his own or from Klaatsch's preparations that the fibrillæ originate without participation of the cells.

He says, "Mir scheint es, man kann nur sagen, dass man die Erscheinung der Schraffirung nur dann konstatiren kann, wenn die Kerne allein in dieser zweiten Schicht nach unten gegangen sind (fig. 7q), aber das heisst doch nicht, dass das Zerfallen in Fibrillen ohne jede Theilnahme der Zellen geschah, um so mehr als während der ganzen Entwicklungszeit der Zwischensubstanz der zweiten Schicht die Zellen in diese Zwischensubstanz versenkt waren und nicht an ihren inneren Rändern lagen; das letztere scheint mir geradezu unverständlich zu sein; diese Schicht ist so dünn, dass an welchen der inneren Ränder—den oberen oder den unteren—man auch diese zellen versetzen möchte, sie doch in der Schicht der Zwischensubstanz liegen würden."

He gives the following summary as to the development of the second layer of the scale:—

(1) "The formation of the layer of intermediate substance precedes the formation of the second layer of the scale; the intermediate substance contains large nuclei embedded in it, whose plasma cannot be distinguished from the intermediate substance itself; that the position of the formative cells is on the inner side of the strips of intermediate substance cannot be urged, in consequence of the insignificant width of that layer.

(2) "Such a substance with large nuclei we find firstly on the floor of the pocket, then beneath the first layer of the scale closely bordering on it.

(3) "This intermediate substance is formed at the expense of the basal elements of the papilla. As to the possibility that the fibrillæ of the second layer of the scale may develop themselves at the expense of the intermediate substance by immediate breaking down into such, without participation of the cells, one can say nothing definite, for the reason that there is no possibility of distinguishing the plasma of the formative cells from the intermediate substance itself."

The reliefs on the surface of scales. Ussow has only studied the formation of these reliefs in cycloid scales. In perfectly developed scales this relief has most frequently the form of rolls or cylinders, which cover the entire surface of the scale and run parallel to its border. In sections the rolls generally appear as small elevations of transparent homogeneous material, the appearance of which does not differ from that of the first layer of the scale. One finds a cell on such a roll or often behind it. The question might at once be asked, Where do these cells come from? Klaatsch says that these cells make their appearance out of the connective tissue of the scale pocket, and that as they penetrate into the intermediate space between the epidermis and the scale (in its upper part which has penetrated into the epidermis) as well as between the lower part of the scale and the pocket, they arrange themselves on the external surface of the scale in curved rows, and form, always in front of themselves, the substance out of which the rolls are made. Ussow saw such aggregations of cells in his sections, but in distinctly later stages than those figured by Klaatsch, namely when the reliefs at the sides of the scale are already completely formed; but at the stage when those reliefs occurred for the first time, no such cell aggregations existed. Ussow regards it as very possible that these cells later take part in the formation of the reliefs, but he believes that the commencement of their formation arises at the expense of the peripheral elements of the papilla, and that for the following reasons: "Commencing with the stage of a plate of scleroblasts, one finds in all subsequent sections the following formation: at the ends of the scales one observes masses of cells which differ in form and colouring from the scleroblasts of the plate, and are similar rather to the peripheral and basal elements of the papilla; they are, namely, much smaller than the scleroblasts and stain more deeply; in a word, they are cells which have taken no part in the formation of the scale, as the cells which form the scale change their form and appearance, their nuclei become larger, get a pear-shaped form, and are not so intensively stained. In following stages, tooth-like projections formed of transparent substance become observable at the ends of the plate, where the cell-masses were situated; behind each tooth lies a cell, or more properly only its nucleus, for the plasma has apparently been spent in the formation of the roll or cylinder which appears as a tooth in transverse section."

In connection with cycloid scales, Ussow believes that the teeth or small spines are not in any true sense comparable to rudimentary forms of the spines of placoid scales either in internal structure or development, but that there is merely an external resemblance. He holds that these spines are built of the same substance as that of the entire upper substance of the scale, that is to say, according to Hofer, of hyalodentin.

Ussow concludes his paper in the following words:—

"The scale of Teleosteans is a plate consisting of two layers. The upper layer (including the relief) consists of homogeneous tissue without any structure (frequently one can, however, observe on focussing a slight striation running parallel to the upper surface of the scale). This layer originates at the expense of the mesoderm elements of the dermis, at the expense of the so-called scleroblasts; its inorganic portion consists of amorphous calcium phosphate. The tissue of this layer is an ordinary simple bony tissue.

"The lower layer of the scale also originates at the expense of the same mesoderm elements. It is formed in part out of indurated (sclerosirten) connective-tissue fibrillæ, between which no cells exist (in the species investigated by me). One terms its tissue a tense connective tissue."

The next paper which I notice, that by Hoffbauer* on the "Age-determination of carp by means of their scales," bears more distinctly on my own contributions on the scales of marine fishes than any of the papers previously mentioned. Dr. Hoffbauer's work is that from which my investigations had their origin, and I would therefore lay all due stress upon it. This author showed that carp bred in pond or aquarium, for all of which he had exact knowledge as to their age and history, possessed in their scales a means of age-determination.

The scale of a carp shows the following structure:—There are two distinct areas, firstly, a non-transparent part covered by the upper skin, and situated towards the tail of the fish, which may be termed the posterior field or area; and a transparent part enveloped in the scale pocket, which may be called the anterior field or area. Only the anterior area comes into consideration in the determination of age. This anterior field, as distinguished from the posterior, shows fine lines which run approximately parallel to the margin of the scale, and apparently take their origin from a more or less median point lying back towards the posterior area of the scale. This median point is the centre of growth, and constitutes the oldest portion of the scale, characterised by the absence of lines or striæ. He describes these lines or striæ in the anterior area of the scale as concentric lines or striæ, which show much similarity in their arrangement to the annual rings seen in the transverse sections of trees. The concentric lines consist of ridge-like elevations of the upper surface of the scale, in consequence of which the upper surface is rougher to the touch than the under surface. The formation of these concentric lines has a very close connection with the growth of the scale. According to Baudelot, the lines are due to the fact that the lower surface of the scale, consisting only at first of a small thin plate (the centre of growth), gradually lays down lamellæ which always become larger in peripheral circumference, and on their free projecting margins concentric lines form themselves. It was at one time believed that a new lamella was formed each year, and that the concentric lines were the thrown up projecting margins of individual lamellæ; for example, that a twelve-year-old fish had twelve individual lamellæ and twelve concentric lines corresponding to the number of lamellæ. In a previous paper Hoffbauer showed that this accepta-

* Hoffbauer, 1899.

tion was incorrect (Allgem. Fischerei-Zeit, 1898, Nr. 19), as firstly the number of lamellæ is not the same as that of the concentric lines, and secondly the total number of concentric lines is much greater than the number of years. The number of concentric lines which form themselves at the free margin of the lamella stands, however, in direct relationship with the growth of the latter. As a result of this, the comparative distance of the concentric lines from one another also changes; it is greatest at the time of greatest growth, that is to say, in the summer.

He gives a diagrammatic transverse section of the scale of a two-year-old carp. He notes the difficulty of investigations dealing with the compounding of the lamellæ, that is to say, their number in relation to the size of the scale and their relation as a foundation for the concentric lines, as the hardness of their material renders it difficult to secure intact sections. In addition to the concentric lines, there are also radial lines on the surface of scales, the arrangement of which he considers to be of some service in the determination of age. He notes the presence of scales which differ in their structure from that described above. This variation from the normal consists of an expansion of the centre of growth so that it sometimes comes to occupy quite an extensive area, and there is a corresponding reduction of the number of concentric lines; but other scales from the same carp will show usually the normal arrangement. This deformity shows itself in very intensively developed carp, whose quick growth is expressed in the structure of the scale which does not form concentric lines to the usual extent.

Age-determination from the scale. The hypothesis upon which, in the first place, his method rests is the mode of the carp's life.

"It is clear, that in an animal which has a so-called winter sleep, whose means of nourishment decreases in autumn at the commencement of colder days, and whose body-weight remains the same in winter-time even under the most favourable circumstances, while in warm months much growth takes place as a result of a rich supply of nourishment, this reaction makes itself evident in a corresponding manner by changes in the structure of the body. We find that this phenomenon is shown, not only in every animal with such a mode of life, but it is true also in the plant world."

He believes that this change in the nourishment of the fish in summer as contrasted with winter shows itself in the scale as well as in other organs of the body; but the former is particularly well adapted in its structure to show the effect of the change.

He says, "As I have now investigated hundreds of carp scales with the most favourable results, I may indeed accept with complete assurance the truth of my hypothesis."

He acknowledges that one finds individual scales from which age-determination would be difficult, and that there are other scales which would tend to make the inexperienced worker very doubtful; but the uncertainty disappears after observing several scales from the same fish, as among them some would be found showing more distinct demarcations.

He then describes the superficial structure of a scale taken from a carp at the end of its second summer, namely, in late autumn, as illustrated by a photomicrograph. The means of determining the age is, as previously mentioned, found in the arrangement of the concentric lines on the scale surface. The best way to observe the arrangement of those lines is to begin at the centre of growth, and to pass straight outwards to the median border of the anterior area. The first lines round the centre of growth are rather irregular and interrupted, and are comparatively widely separated from one another; then follow more regular lines, which lie close to one another until they run into a bordering zone appearing somewhat darker. This zone marks the end of the first year's growth. In the second zone (the second year's growth) the arrangement of the concentric lines shows a repetition of that occurring in the first year, namely, firstly, irregular lines comparatively separated from one another; secondly, more regular lines with little separation between them. In scales of carp observed at the end of the third summer, a third zone shows itself similar in general arrangement to the last. "The number of concentric lines within a year's zone is, in individual scales from a scale row of the same carp, running, for example, close above or beneath the lateral line, approximately the same. Their number only decreases at those places where the scales themselves become smaller, as at the gill-slit and at the tail; the number is also only subject to slight fluctuations in corresponding scales on the right and left sides of the same individual fish; in corresponding scales from different individuals it can, however, vary considerably, according to more or less intensive growth within a year."

He gives a statistical table to bring out these points, in which he shows the number of concentric lines in individual scales in the row of scales dorsal to and above the lateral line in the direction from the gill-slit to the tail. The structure described above is seen in all normally formed scales, that is to say, from carp living under favourable and natural conditions. He, however, also considers less favourable conditions. The fish's growth may have an irregular course, it may grow faster or slower. For example, what influence has illness, or want of food, or both of these, for one or several years upon the method of age-determination.

But, "in this case, the structure of the scale does not leave us in a difficulty; on the contrary, we gain from it, in a manner, a self-registering, infallible control over the mode of life of its bearer." He takes a case to show this point. He commences with the most unfavourable case: the case of a carp in its third summer which had grown slowly all its life in consequence of less food. This mode of life showed itself in the arrangement of concentric lines at an equal distance from one another within a period of growth. As a result of this, the border separating one year from another becomes more indistinct. As a rule, one sees a divergence of the concentric lines at the age border where the posterior area meets the anterior area at the right and left of the concentric lines. If one follows this divergence towards the front margin of the anterior field, then the separation area between one year and another becomes more distinctly marked out than one had hitherto supposed, or rather observed. Besides this, the radial lines also aid one in age-determination. It is frequently the case that at the border between one zone and another, either several radii of the previous year's zone end, or new radii of the succeeding year's zone begin. Lastly, the total number of concentric lines is a sure way of dispelling all further doubts on the subject.

One does not need a detailed observation such as the above to distinguish a slow-growing carp of three summers from a well-grown carp of two summers, as superficially the difference in the distance of the concentric lines, in such a two-year carp of approximately the same size, is distinctly greater at its chief period of growth, and besides this, the age border between the first and second year is also much more distinct. With practice one can in a similar way distinguish between a slow-grown carp of two summers and a quickly grown carp of one summer. The age-determination of rapidly grown carp offers no difficulty, the difference in the distance of the concentric striæ appears distinctly prominent at the time of the growth period. One may lay down the following general rule in regard to the relationship of the concentric lines :—

"*Je intensiver das Wachstum der Karpfen, respektive seiner Schuppe, um so grosser wird der Abstand der konzentrischen Streifen von einander und umso unregelmässiger, unzusammenhängender ihr gegenseitiger parallel Verlauf.*"

He shows, from his figures that from spring until the height of growth in the summer months a steady increase of the distance of the concentric striæ appears, which finally are represented as zigzag lines partly anastomosing with each other. In autumn the lines become much closer to one another, until finally they become extremely close and regular. In some cases in the first year's zone, in consequence of a great expansion of the centre of growth, concentric lines are not formed in spring-time, but only in summer-time.

Under some circumstances, however, an intensive growth may take place in spring-time, as shown in fig. 6 (Hoffbauer). This figure shows that the concentric striæ at the commencement of the second year have a very regular course and are at a great distance from each other. In other figures he shows how much the centre of growth may expand; thus in fig. 8, representing the scale of a one-summer carp, only twenty irregular concentric lines have been formed at the conclusion of the growth period, while under normal conditions fifty to sixty and more are to be seen. Further, in fig. 9 the first year's zone is altogether without concentric lines, which only commence their formation at the beginning of the second year. Even the second year's zone may have no concentric lines, as he shows in his tables giving the number of concentric lines; this is, however, a rare occurrence.

The remainder of his paper is taken up with a consideration of photomicrographs of scales from carp bred in pond or aquarium, for all of which he had exact knowledge as to their age and history, and to my mind these figures show in a very clear and interesting manner the truth of this mode of age-determination. He shows that in carp, the scales of which were periodically examined, the increase in the dimensions of the size of the scales, the number of concentric lines formed in them, and the amount of separation between the lines, corresponded with the known facts as to whether the fish were slowly or quickly gaining weight, and this in a very striking manner. He says, "Die Unterschiede sind so deutlich erkennbar, dass wir uns eine bessere und untrugliche Orientirung gar nicht verschaffen können." He further takes up the case of two carp of the same brood and of equal weight; one of these was put into an aquarium, the other into a pond at the same time, their scales being first examined. The carp placed in the pond naturally gained weight more quickly than that placed in the aquarium, and on the scales of both being examined some time later, those from the pond showed an increase of scale surface, with widely separated concentric lines, while those from the aquarium showed little increase of scale surface and closely situated concentric lines. The increase in the case of the pond fish he ascribes to the supply of plankton food from the water. Another interesting case is that of carp whose growth was partly disturbed for a time by an accidental drying up of the water in the pond in which the carp was living. On the scales of this carp being examined some time after the renewal of the supply of water, the effect of the partial drying up and subsequent renewal of the water appears marked out in the scales, the adverse condition by dark closely situated lines lying close together, the normal condition by clear and more widely separated lines. During the partial drying up of the pond, the fish were probably deprived of their wonted nourishment.

In conclusion, he deals with the case of an invalid carp. When this carp was caught it appeared thin and poorly nourished. On examination this appeared to be due to a swelling in the anal region. The scales seemed clearly to show at what time this swelling had effected a disturbance in the growth of the animal. He concludes his first paper on this subject by saying that age-determination from the scales will not probably be so easy in carp older than three years, as the older the carp becomes the larger and thicker do its scales become, and consequently they are not so transparent, and recognition of the concentric striæ becomes more difficult, especially in the first year's zone surrounding the centre of growth.

In the following year Dr. Hoffbauer issued a second paper, a continuation of the last noticed. His subject is now somewhat wider, namely, "Further contributions on the structure of fish scales for determination of the age and course of growth."* In this paper Hoffbauer strengthens his position by means of further results and statistics, and also replies to certain criticisms by Dr. Walter (*Jahresberichtes in der Fischerei Zeitung*, Bd. iii., 1900, Nr. 19). Walter had allowed the general correctness of Dr. Hoffbauer's observations, but had regarded them as less certain and easy of recognition for practical men than for Dr. Hoffbauer.

Hoffbauer regards Walter's position as largely due to unnecessary methods which he employed in cleaning scales, by which the characteristic features of the scale became less apparent.

In this second paper Hoffbauer, in addition to extending his observations on the scales of the two varieties of carp treated of in his first paper, includes those of *Carassius carassius*, L., *Micropterus salmoïdes*, and *Perca lucioperca* in his observations with equally good results.

In January, 1902, I published a preliminary paper on the same subject as my present contribution.†

From this paper I quote the following paragraphs :—

"The formation of these annual rings results from the fact that the lines of growth on the scale surface are comparatively widely separated from one another in that portion of the scale formed during the warmer season of the year; but much less widely separated in that part built up during the colder

* Hoffbauer, 1901. † Thomson, 1902.

season. Thus by following the arrangement of the lines of growth on scales, it is a simple matter to observe the starting-place of any year's growth by the comparatively wide separation of the growth-lines at that portion of the scale, and in this way the surfaces of scales appear mapped out by annual rings. These annual rings supply us with an index as to the age of the fish, and may be roughly compared to the rings in many trees. The annual rings in the stems of trees are due to seasonal nutritive conditions, and the rings on the scales of fishes are probably the result of seasonal environmental conditions, such as food, temperature, etc. In more detail, the alternate occurrence of comparatively rapid and slow areas of growth in scales is probably the result of the variations in food, temperature, etc., which are associated with the alternation of summer and winter. For example, the abundant supply of food (plankton, etc.) during the warmer season of the year probably has much connection with the comparatively rapid growth of the scale at that time as compared with the slow increase during the colder season, when there is a decrease in the supply of food.

"These facts appear to possess both scientific and economic importance, since they permit the extension to marine fishes of a new system of age-determination by means of these annual rings on scales, a system which has recently been shown and demonstrated by Dr. Hoffbauer for the carp.

"I hope to illustrate clearly the mode of formation of annual rings in Gadoid scales by the aid of the figure on the accompanying plate.

"The figure [Plate II., Fig. 1, of the present paper] represents the scale of a pollack, 28·5 centimetres ($11\frac{1}{2}$ inches) in length, captured towards the end of October. A minute translucent area (see Fig. 1, C) devoid of any lines is situated towards the narrower and more internal end of the scale; and around this area, which is the first portion of the scale to be formed, are grouped numerous excentric lines of growth similarly disposed to the excentric layers in the starch grains of the potato.

"The excentric lines of growth on this scale, however, are arranged in such a manner (see figure) as to map out its surface into two main regions, namely, an internal area, which is the entire growth of the first year, and an external part, the summer growth of the second year. One understands how these two areas appear so distinctly if one follows the lines of growth outwards from the translucent area to the broader and more external part of the scale. One may firstly observe that there are nineteen lines comparatively widely separated from one another, which indicate the growth of the first summer, and secondly, ten lines less widely separated, indicating growth of the first winter. External to these there follows an area showing much more widely separated lines of growth, which indicate the scale growth of the second summer.

"The difference between the lines of growth formed during the second summer and those of the preceding winter is so apparent as to clearly define the termination of the first year's growth. The widely separated lines of the second summer number nineteen, and as the pollack from which this scale was taken was captured in October, it appears that in this scale the number of lines formed during the second summer exactly agrees with the number formed during the first summer."

I must conclude my review of the literature of scales, so far as it bears on the subject of my investigations, with a notice of a preliminary paper by Dr. Marett Tims.* This paper deals with later stages of scales than those of Klaatsch and Ussow.

The scales observed by Marett Tims were from several species of Gadidæ—*Gadus virens*, *G. luscus*, *G. pollachius*, *G. callarias*, etc. As this paper is very brief, I content myself mainly by quoting several of his sentences.

"The formed scale is a compound structure consisting of a fibrous stratum, upon the upper surface of which are situated numerous 'scalelets,' arranged in lines radiating from a more or less homogeneous centrum. It is the presence of these structures that gives the 'sculptured' or 'ringed' appearance to the scales; but these terms, though frequently applied, are misleading."

"The fibres (of the fibrous stratum) are arranged in definite layers: (1) a superficial, in which the bundles are concentric; (2) a deep layer, in which the individual bundles interlace with one another at right angles, each set running diagonally to the long axis of the scale. A third layer, the fibres of which form an irregular network, is possibly present, but it is much more difficult to demonstrate."

"The scalelets, placed upon the upper surface of the fibrous stratum, are themselves covered with a delicate epidermis. . . . They consist of flattened, imbricated, calcareous plates."

He infers from reactions with borax-carmine and acid that in the earlier condition the scalelets "are more thoroughly calcified, or rather, perhaps, that in the later stages they contain a larger amount of organic material, and thus stain more readily."

"Between the radiating lines of scalelets the deeply stained fibrous stratum is seen, resembling the spokes of a wheel.

"In an early stage, before the scalelets become imbricated, the fibres may also be noticed as transverse bands passing between the individual plates of a row.

"On examining a section of an undecalcified scale, the scalelets are seen to be for the most part implanted in sockets on the upper surface of the fibrous stratum with a varying inclination. Those at the centrum appear to have fused, forming a horizontal plate, while at the periphery of the scale they are almost perpendicular. In a section through the skin of a green cod about 4 cm. long the individual scalelets are quite isolated. Each consists of a basal plate, from the upper surface of which projects a minute spine, thus resembling a small placoid scale.

"Such a condition is only evident in material from which acid has been rigidly excluded. The condition does not appear to have been previously noted; the figures given by Klaatsch and others being similar to those which I obtained from material which has been passed through acid alcohol, and which do not show the true nature of the scale."

If the forecasts of the results of this paper are true, they necessarily invalidate many ideas previously held as to the nature of scales, and must also introduce quite a new set of terms in their description. I prefer, however, to keep cautiously to the older and more established views and terms until

* Marett Tims, 1902.

Dr. Marett Tims's facts may be affirmed by the publication of his detailed paper, to which I look forward with much interest.

[Since Mr. Thomson left for South Africa, Mr. A. W. Brown, of St. Andrews, has been good enough to send me a reprint of a note communicated by him to the Royal Society of Edinburgh (*Proceed. Roy. Soc. Edinburgh*, 1902–3, p. 437), entitled "Some Observations on the Young Scales of the Cod, Haddock, and Whiting before Shedding." This note is as follows:—

"During the winter of 1902–3, I conducted observations upon the scales and their condition, in several of the gadoid fishes. Investigation was commenced in October, 1902; but it was not until the beginning of March 1903 that the first appearance of the young scale took place. In stained specimens, it can be recognised as a deeply staining 'nucleus,' lying beneath the old scale, just under its centre. Such an appearance was found in cod, haddock and whiting of all ages from one to three or four years; and, in all, the young scale is clearly recognisable, underlying the old. As soon as these fishes have spawned, they appear to shed their scales, the epidermis first peeling off. An examination of a few large haddocks, eight pounds weight and over twenty-seven inches in length, showed that in January the ovary was black, shrunken, and not in spawning condition. I am inclined to think that these fish are past the age for spawning. I examined very carefully this class of haddock right on till April. In every case I found that the scales showed evidences of hard wear, and in some cases were frayed. In these fishes no traces of the replacing scales were found, and the probable conclusion is that no further shedding of the scales takes place after the close of the reproductive period.

"It has been suggested that the annual rings of growth may be traced upon the gadoid scales; but I find that upon the cod, haddock, whiting, green cod, and pollack, of one to three years of age, scales may be obtained from different parts of the body showing ninety, sixty, or thirty rings, according to the part selected.

"I have been enabled to trace back the first appearance of the new scale to the month of February, when it may be recognised as a dark tip growing upon a small papilla.

"By the middle of April, the epidermis on the head commences to peel off, and, probably somewhat later, over the body. The details of this process will have to be followed in sections; but sufficient evidence is to hand to make it probable (1) that gadoid fishes shed their scales immediately after spawning; (2) that after the age limit of spawning is reached no further shedding of scales takes place; (3) that the concentric rings of the scales do not represent annual increments, but must have other causes."

Mr. Thomson had heard verbally of this communication, but had not seen the note. He states that the presence of minute scales amongst the larger ones in the trout was described and figured by Klaatsch in 1891, and their presence in Gadidæ has been known to him for two years. He refers to these small scales in another part of this paper (p. 57), and does not attach to them the same significance as that given them by Mr. A. W. Brown. —E. J. A.]

III. Statistical Section.

This section of my paper is chiefly concerned with measurements of the surface size, enumeration of the lines of growth and annual rings for scales of the following: pollack, poor-cod, whiting, haddock, and cod.

The area of the body from which scales were generally selected for examination was the median region of the flanks, that is to say, slightly posterior to the pectoral fin, and either slightly above or below the lateral line.

In the majority of cases I have given data in the tables for half a dozen scales from the same fish, three of which were taken from the right side, and the other three from the left side of the body.

Scales from any part of the body show annual rings, though scattered among the normally developed scales are some minute scales mentioned by Klaatsch, to which I will later refer. Of the five species mentioned above, that which shows annual rings in the scales least satisfactorily is the whiting; so much is this the case that at times their determination becomes a matter of real difficulty, and it is only after a comparison of the lines of growth in scales from a number of specimens that one attains any degree of certainty in the matter. The other species mentioned show annual rings remarkably clearly, much more so, indeed, than is brought out in the photomicrographs. The coal-fish (*Gadus virens*) and the Norwegian whiting-pollack (*Gadus Esmarkii*) also show annual rings very distinctly (see plates), and I only regret that want of time prevents my giving statistics for these two species. In regard to the cod, *Gadus callarias*, L., from photomicrographs which I have taken, it appears that the system would also be applicable to this species; but not having a complete series of this fish, I have only given a few figures, and more exclusively confined my attention to Gadidæ of the English Channel.

In passing, I may say that I approached the subject of the age of fishes with an unbiassed mind, as I had little previous knowledge as to the ideas of either practical or scientific men on this subject, and it was only after I had compiled my own statistics on age-determination that I compared my results with those arrived at by other workers by different methods (see Cunningham, Fulton, etc.).

The determination of the years of large and aged fish from their scales is a much harder task than in the case of younger fish, as the scales of the former have, firstly, become much thicker and less transparent, and secondly, the scales of such are frequently more or less disintegrated. As an illustration of this one may notice the photomicrograph of a scale of a pollack 31 inches in length, which appears to possess 8 annual rings (see Plate IV.).

That in the life of fish, as in trees, there will be good years and bad years is more than probable, and as this variation in metabolism expresses itself in the stems of trees, one might, reasoning from analogy, expect a similar change in the scales of fishes. That such an effect does take place appears probable from my figures and photomicrographs.

In regard to locality of capture, as my work was mainly done at Plymouth, most of the fish examined were from the western portion of the English Channel, chiefly from the bays of Devon and Cornwall. Few of the fish examined were captured by the ocean-going trawlers, as in fish caught by this method the scales were, as a rule, completely rubbed off by the time the fish came to hand.

If, as in the case of a few whiting, etc., the fish examined were captured at other localities, I have stated that such is the case in the column of notes.

The haddocks examined were caught in the North Sea, off the Firth of Forth, in Aberdeen Bay, and off the Shetlands.

The cod, only a very few statistics about which I am able to give, were brought in at St. Andrews.

A friendly critic has suggested that annual rings would either not be found, or would not be clearly marked, in scales from fish of deep water, on account of the fact that in this case fish are not exposed to the same seasonal variation in temperature as in shallow water; in other words, is it not probable that the growth of fish living in deep water will be less accelerated in the summer and less arrested in the winter than in forms living in shallow water. In order to determine if such was the case, I compared scales from a series of haddock (10–15 inches in length) captured in comparatively shallow water (8–14 fathoms) at Aberdeen Bay with another series (10–16 inches) caught in deep water (60–80 fathoms) seven miles off the Shetlands. The result of my observations was that annual rings were as clearly marked in the scales of haddocks from deep water off the Shetlands as in those from shallow water of Aberdeen Bay, excepting that in the older stages of the former the rings appeared very slightly less clearly defined.

The weights of fish in the statistical tables must be slightly allowed for as not being exactly accurate, as in most cases the fish were weighed after having been for some time in spirit or formalin.

THE OCCURRENCE OF MINUTE SCALES.

In my observations on the skin of Gadidæ I noticed the presence of minute scales situated near the larger and better developed. These minute scales I found chiefly in the younger stages of the fish. In older stages of the animal they appeared to be almost entirely covered over by the larger ones, and to lie in such positions that their growth would apparently be much hindered by the latter. The small scales do not appear to be arranged on the skin in the regular manner characteristic of the larger scales, and they do not possess many lines of growth. According to my opinion, these minute scales never grow to any size, and can always be distinguished from the better-developed and more regularly arranged scales. In the early stages I believe that the diminutive scales lie freely and are not covered over by the larger scales; but as these larger scales grow, they cover over the smaller scales and hinder their growth, consequently the latter either remain small or disappear altogether. That these minute scales grow and later take their place alongside of the larger scales I do not believe. We have also to remember in this connection that the exact number of scales in a row on the fish has been regarded as sufficiently constant for use in the determination of species.

Klaatsch has referred to these small scales in two connections, firstly, in the development of the trout, and secondly, in a comparison of the teleostean with the placoid scale. He also gives a figure of these small scales in a young trout. In his section dealing with the development of trout scales he says that at the same place in a fish one finds scales which are by no means similarly advanced in development. Between such large scales as already partly cover one another, small scales are very frequently found which are in the earliest stages of development. In older animals such an irregularity does not occur.

In his section dealing with a comparison of the teleostean and placoid scales, he says that the arrangement of the rhomboid scales on the skin of the trout is similar to the arrangement of the rhombic basal plates of the dogfish; both of them are arranged in oblique rows. There is a further point of similarity. As in Elasmobranchs, new scales originate in the trout between the well-developed scales; thus one finds lying between the older scales of the trout even in later stages quite young scale foundations. This irregularity in the early development soon ceases in the trout.

The Pollack *(Gadus pollachius)*.

The following tables give detailed measurements of the surface size, number of lines of growth, and annual rings for scales of pollack, which varied from about $1\frac{3}{4}$ inches to 33 inches in length. According to Cunningham, on the coast of Cornwall the spawning of the pollack commences in February or March, and the young of the year are found in April. In that month they are from $\frac{8}{10}$ to 1 inch in length, and he estimates their age at approximately six weeks.

In 1901 I found fish of the latter size, at the beginning of May, possessed of extremely minute scales without any lines of growth.

Pollack $1\frac{3}{4}$–$2\frac{3}{4}$ inches in length, caught on 8th July, would thus be about three months old, and these show, on an average, 3–4 lines of growth, thus giving a formation of 3–4 lines in two months.

Cunningham further says, "In October I have taken a number in Cawsand Bay, $3\frac{1}{5}$–$4\frac{2}{5}$ inches long, and I have no doubt these were hatched in the preceding spring."

I have examined Cunningham's actual specimens, and the scales of these give on an average 15 lines of growth, and their structure bears out his statement, and gives a formation of approximately 2–3 lines of growth per month.

Two months later, in December, there are an average 18 lines of growth, giving an addition of 1–2 lines of growth per month. One would naturally expect to find fewer lines of growth during these winter months. In another sentence Cunningham says, "The pollack caught in Plymouth Sound in June and July are 12–15 inches long, and are probably in their third year."

This is also brought out in my table. It will be seen there that a fish 15 inches long captured in the middle of June has 2 annual rings and 7 young lines of growth occurring on its scales.

If growth for the third year started in the middle of April, this again would give a formation of about 3 lines per month.

In the following detailed tables dealing with the pollack, I have given a comparison of scales from four different regions of the body in two cases, firstly, that of a young fish (3·79 inches), and secondly, that of an older fish (15·19 inches). The four regions of the body from which scales were examined in these two cases were the following:—

(1) The anterior region, laterally, slightly posterior to the eye.
(2) The median region of the flanks, that part of the body which has the greatest depth vertically beneath the first dorsal fin and posterior to the pectoral fin. This has been the usual area from which I have examined scales throughout my investigations.
(3) Region vertically beneath the posterior part of the second dorsal fin, adjoining the lateral line.
(4) Region vertically beneath the third dorsal fin, adjoining the lateral line.

In a comparison of scales from these four regions the following facts may be noticed:—

(1) That commencing with the anterior area and proceeding backwards to the posterior area, the number of lines of growth increases in both the young and older fish.
(2) That proceeding in the same direction, the length of the scale increases in a similar manner.

(3) That the length of the axis AB^1 or AB^n (axis from centre of growth to posterior end of scale) increases in a corresponding way.

(4) That in young fish the broadest scales are those taken from the median region of the flanks (second region); but in the case of the older fish the broadest scales are those from the third region, namely, vertically beneath the second dorsal fin.

I have selected that region vertically beneath the first dorsal fin as the area from which I usually take scales for examination for several reasons: firstly, that it is the area from which previous workers have taken scales; secondly, that this is, according to Klaatsch, Ussow, etc., the region in which scales first develop; thirdly, that in the case of fish in which the scales have been rubbed off by mechanical friction, this area appears to retain them longer than others. This may be because it is partly protected by the pectoral fin.

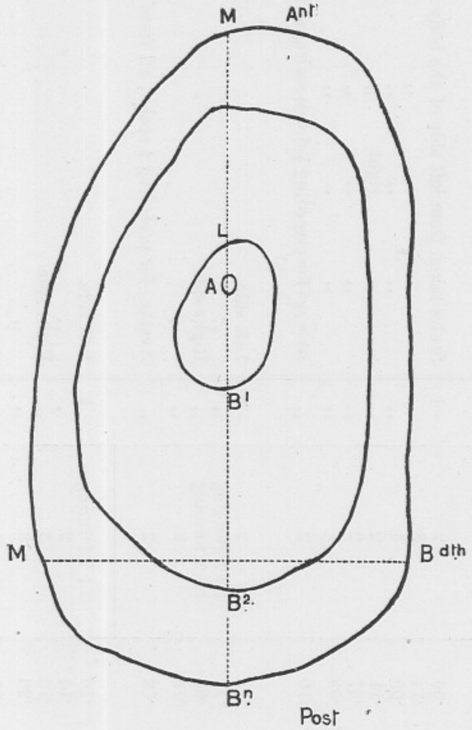

Fig. 1. Diagram of a pollack's scale with three annual rings to show the mode of measurement adopted in the statistical tables.

Ant = anterior end of scale; Post = posterior end of scale; MB^n = length of scale; MB^{dth} = maximum breadth of scale; AB^n = long axis from centrum to posterior end of scale; LB^1 = total length of 1st year's growth; AB^1 = long axis from centrum to posterior end of Ring I; $B^1 B^2$ = long axis from end of Ring I to end of Ring II in posterior direction; $B^2 B^n$ = long axis from end of Ring II to end of Ring III in posterior direction.

Enumeration of the lines of growth is taken throughout from the centrum in the posterior direction; they are more numerous towards the latter than towards the anterior end of the scale. In the tables the signs + and − are used in connection with the occurrence of annual rings; for example, if no annual rings are as yet formed the term − 1 is used; if one annual ring is complete, and there are additional lines of growth present, the sign 1 + is used.

TABULAR RESULTS OF EXAMINATION OF POLLACK SCALES.

FISH.			SCALES.					REMARKS.
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B in mm.	Number of excentric lines.	No. of annual rings.	
4·4 cm. = 1·73 in.	·64	July 8, 1901	·15	·12	·09	2	– 1	Scales taken from left side of the body of the fish.
,,	,,	,,	·23	·11	·14	3	,,	,, ,, ,, ,,
,,	,,	,,	·20	·13	·09	3	,,	,, ,, ,, ,,
,,	,,	,,	·18	·07	·11	2	,,	,, right ,, ,,
,,	,,	,,	·15	·12	·07	2	,,	,, ,, ,, ,,
,,	,,	,,	·16	·13	·08	1	,,	,, ,, ,, ,,
—	—	—	·18	·11	·10	2	,,	Average for preceding ½-dozen scales, all from same fish.
4·8 cm. = 1·88 in.	·78	July 8, 1901	·23	·16	·14	2	– 1	Left side.
,,	,,	,,	·23	·13	·11	1+1 forming	,,	,,
,,	,,	,,	·18	·10	·09	1+1 forming	,,	Right side.
,,	,,	,,	·22	·12	·13	2	,,	,,
—	—	—	·22	·13	·12	2	,,	Average for preceding 4 scales, all from same fish.
5·4 cm. = 2·12 in.	1·08	July 8, 1901	·25	·14	·16	2+1 forming	– 1	Left side.
,,	,,	,,	·22	·13	·14	2	,,	,,
,,	,,	,,	·28	·18	·16	3	,,	Right side.
,,	,,	,,	·28	·11	·20	3	,,	,,
—	—	—	·26	·14	·17	3	,,	Average for preceding 4 scales, all from same fish.
5·9 cm. = 2·32 in.	1·45	July 8, 1901	·34	·20	·22	4	– 1	Left side.
,,	,,	,,	·33	·21	·22	4	,,	,,
,,	,,	,,	·30	·22	·17	4	,,	Right side.
,,	,,	,,	·34	·22	·21	4	,,	,,
—	—	—	·33	·21	·21	4	,,	Average for preceding 4 scales, all from same fish.

6·1 cm. = 2·40 in.	1·67	July 8, 1901	·26	·18	·18	3	−1	Left side.
,,	,,	,,	·30	·20	·18	3	,,	,,
,,	,,	,,	·30	·21	·18	4	,,	Right side.
,,	,,	,,	·30	·20	·19	3	,,	,,
—	—	—	·29	·20	·18	3	,,	Average for preceding 4 scales, all from same fish.
6·4 cm. = 2·51 in.	1·95	July 8, 1901	·39	·24	·25	5	−1	Left side.
,,	,,	,,	·43	·26	·26	5	,,	,,
,,	,,	,,	·35	·21	·22	4	,,	Right side.
,,	,,	,,	·35	·25	·19	5	,,	,,
—	—	—	·38	·24	·23	5	,,	Average for preceding 4 scales, all from same fish.
7 cm. = 2·75 in.	2·35	July 8, 1901	·39	·22	·23	5	−1	Left side.
,,	,,	,,	·38	·23	·22	5	,,	,,
,,	,,	,,	·32	·24	·22	5	,,	Right side.
,,	,,	,,	·38	·26	·23	5	,,	,,
—	—	—	·37	·24	·23	5	,,	Average for preceding 4 scales, all from same fish.
9·15 cm. = 3·60 in.	6·60	Dec. 4, 1889	·60	·36	·48	15	−1	
,,	,,	,,	·65	·37	·44	16	,,	
,,	,,	,,	·62	·37	·41	16	,,	
,,	,,	,,	·61	·35	·38	15	,,	
,,	,,	,,	·61	·34	·41	15	,,	
,,	,,	,,	·65	·35	·46	17	,,	
—	—	—	·62	·36	·43	16	,,	Average for preceding ½-dozen scales, all from same fish.
9·25 cm. = 3·64 in.	6·22	Oct. 2, 1890	·735	·405	·495	15	−1	The scales being taken at the deepest region of the body, immediately above or below the lateral line (usual area).
,,	,,	,,	·78	·375	·51	15	,,	
,,	,,	,,	·735	·375	·51	15	,,	
,,	,,	,,	·78	·435	·51	15	,,	
,,	,,	,,	·69	·375	·51	15	,,	
,,	,,	,,	·75	·405	·51	15	,,	
—	—	—	·745	·395	·5075	15	,,	Average for above.

TABULAR RESULTS OF EXAMINATION OF POLLACK SCALES—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B in mm.	Number of excentric lines.	No. of annual rings.	REMARKS.
9·50 cm. = 3·74 in.	6·67	Dec. 4, 1889	·61	·39	·49	15	−1	Right side. This fish is comparatively light for its [length, and scale is small.
,,	,,	,,	·62	·34	·41	14	,,	,,
,,	,,	,,	·63	·41	·41	14	,,	,,
,,	,,	,,	·55	·28	·39	14	,,	Left side.
,,	,,	,,	·66	·35	·43	14	,,	,,
,,	,,	,,	·59	·34	·42	14	,,	,,
—	—	—	·61	·35	·43	14	,,	Average for preceding ½-dozen scales, all from same fish. Some of the scales of this fish were disintegrated.
9·65 cm. = 3·79 in.	5·45	Oct. 2, 1890	·86	·39	·60	19	−1	Right side.
,,	,,	,,	·68	·43	·45	14	,,	,,
,,	,,	,,	·67	·40	·43	13	,,	,,
,,	,,	,,	·64	·38	·45	13	,,	,,
,,	,,	,,	·71	·42	·50	14	,,	Left side.
,,	,,	,,	·72	·39	·48	14	,,	,,
,,	,,	,,	·73	·40	·48	14	,,	,,
,,	,,	,,	·70	·40	·43	14	,,	,,
—	—	—	·71	·40	·477	14	,,	Average for preceding 8 scales, all from same fish.
9·65 cm. = 3·79 in.	6	Oct. 2, 1890	·49	·09	·28	8	−1	The following 24 measurements have been made for purposes of comparison of scales from four different regions of the body. Scales taken immediately posterior to eye.
,,	,,	,,	·49	·19	·35	7	,,	
,,	,,	,,	·52	·22	·34	9	,,	
,,	,,	,,	·39	·09	·24	7	,,	
,,	,,	,,	·47	·19	·25	7	,,	
,,	,,	,,	·38	·17	·28	7	,,	
—	—	—	·45	·158	·29	7	,,	Average for preceding ½-dozen scales.

9·65 cm. = 3·79 in.	6	Oct. 2, 1890	·62	·41	·42	12	−1	Scales taken from the usual area, namely, from the median region of the flanks, immediately below the lateral line and posterior to the pectoral fin.
,,	,,	,,	·68	·38	·45	12	,,	
,,	,,	,,	·77	·45	·50	15	,,	
,,	,,	,,	·75	·45	·53	15	,,	
,,	,,	,,	·69	·50	·41	14	,,	
,,	,,	,,	·72	·51	·50	15	,,	
—	—	—	·71	·45	·47	14	,,	Average for preceding ½-dozen scales.
9·65 cm. = 3·79 in.	6	Oct. 2, 1890	·87	·46	·68	18	−1	From same fish, near lateral line, vent. to 2nd dors. fin.
,,	,,	,,	·86	·44	·56	17	,,	,, ,, ,, ,,
,,	,,	,,	·95	·30	·67	19	,,	,, ,, ,, ,,*
,,	,,	,,	·75	·35	·49	16	,,	,, ,, ,, ,,
,,	,,	,,	·88	·45	·58	18	,,	,, ,, ,, ,,
,,	,,	,,	·83	·41	·55	17	,,	,, ,, ,, ,,
—	—	—	·86	·40	·59	18	,,	Average for preceding ½-dozen scales.
9·65 cm. = 3·79 in.	6	Oct. 2, 1890	·77	·34	·49	17	−1	From same fish, near lateral line, vent. to 3rd dors. fin.
,,	,,	,,	·94	·51	·61	18	,,	,, ,, ,, ,,
,,	,,	,,	·99	·40	·68	20	,,	,, ,, ,, ,,
,,	,,	,,	1·04	·37	·73	20	,,	,, ,, ,, ,,
,,	,,	,,	·83	·39	·61	20	,,	,, ,, ,, ,,
,,	,,	,,	·95	·38	·67	19	,,	,, ,, ,, ,,
—	—	—	·92	·398	·63	19	,,	Average for preceding ½-dozen scales.
9·85 cm. = 3·87 in.	9·25	Dec. 4, 1889	·81	·47	·58	20	−1	
,,	,,	,,	·78	·44	·56	21	,,	
,,	,,	,,	·70	·54	·59	19	,,	This scale was unusually broad.
,,	,,	,,	·83	·40	·63	22	,,	
,,	,,	,,	·85	·50	·62	22	,,	
,,	,,	,,	·78	·44	·54	19	,,	
—	—	—	·79	·465	·59	21	,,	Average for preceding ½-dozen scales, all from same fish.

* Abnormal as to breadth.

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B in mm.	Number of excentric lines.	No. of annual rings.	REMARKS.
10 cm. = 3·93 in.	9·45	Dec. 4, 1889	·76	·43	·55	18	–1	Right side.
,,	,,	,,	·77	·35	·68	22	,,	,,
,,	,,	,,	·80	·49	·61	21	,,	,,
,,	,,	,,	1·20	·50	·68	19	,,	Left side.
,,	,,	,,	·79	·38	·56	18	,,	,,
,,	,,	,,	·84	·42	·58	19	,,	,, A few scales from this fish were in a dis- [integrated condition.
—	—	—	·86	·43	·61	20	,,	Average for preceding ½-dozen scales, all from same fish.
10·15 cm. = 3·99 in.	7·5	Dec. 4, 1889	·73	·40	·48	18	–1	
,,	,,	,,	·70	·45	·46	17	,,	
,,	,,	,,	·73	·43	·53	20	,,	
,,	,,	,,	·79	·42	·54	19	,,	
,,	,,	,,	·67	·41	·45	17	,,	
,,	,,	,,	·84	·40	·61	21	,,	
—	—	—	·74	·42	·545	18	,,	Average for preceding ½-dozen scales, all from same fish.
10·20 cm. = 4·01 in.	8·20	Dec. 4, 1889	·60	·31	·42	14	–1	Right side.
,,	,,	,,	·65	·38	·47	16	,,	,,
,,	,,	,,	·74	·42	·51	18	,,	,,
,,	,,	,,	·70	·40	·54	17	,,	Left side.
,,	,,	,,	·73	·43	·54	18	,,	,,
,,	,,	,,	·65	·35	·48	17	,,	,,
—	—	—	·68	·38	·49	17	,,	Average for preceding ½-dozen scales, all from same fish.

10·25 cm. = 4·03 in.	8·92	Oct. 2, 1890	·94	·45	·65	15	−1	Left side.
,,	,,	,,	·88	·48	·62	16	,,	,,
,,	,,	,,	·95	·46	·65	16	,,	,,
,,	,,	,,	·85	·42	·58	16	,,	Right side.
,,	,,	,,	·87	·51	·58	16	,,	,,
,,	,,	,,	·89	·49	·57	17	,,	,,
—	—	—	·90	·47	·61	16	,,	Average for preceding ½-dozen scales.
10·35 cm. = 4·07 in.	8·30	Oct. 2, 1890	·77	·42	·56	16	−1	Left side.
,,	,,	,,	·81	·44	·55	16	,,	,,
,,	,,	,,	·90	·51	·545	16	,,	,,
,,	,,	,,	·82	·44	·59	17	,,	Right side.
,,	,,	,,	·75	·40	·54	16	,,	,,
,,	,,	,,	·82	·45	·57	15	,,	,,
—	—	—	·81	·44	·56	16	,,	Average for preceding ½-dozen scales, all from same fish.
10·45 cm. = 4·11 in.	8·45	Oct. 2, 1890	·90	·48	·63	17	−1	Left side.
,,	,,	,,	·91	·50	·61	17	,,	,,
,,	,,	,,	·85	·42	·53	16	,,	,,
,,	,,	,,	·83	·49	·58	16	,,	Right side.
,,	,,	,,	·77	·44	·50	16	,,	,,
,,	,,	,,	·82	·48	·55	16	,,	,,
—	—	—	·847	·47	·566	16	,,	Average for preceding ½-dozen scales, all from same fish.
10·55 cm. = 4·15 in.	8·10	Oct. 2, 1890	·88	·50	·61	16	−1	Left side.
,,	,,	,,	·91	·49	·61	15	,,	,,
,,	,,	,,	·80	·34	·57	14	,,	,,
,,	,,	,,	·78	·48	·54	15	,,	Right side.
,,	,,	,,	·88	·45	·57	15	,,	,,
,,	,,	,,	·79	·42	·57	15	,,	,,
—	—	—	·84	·447	·58	15	,,	Average for preceding ½-dozen scales, all from same fish.

TABULAR RESULTS OF EXAMINATION OF POLLACK SCALES—*continued.*

FISH.			SCALES.					REMARKS.
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B in mm.	Number of excentric lines.	No. of annual rings.	
10·75 cm. = 4·23 in.	6.95	Oct. 2, 1890	·84	·43	·55	16	– 1	Left side.
,,	,,	,,	·83	·43	·57	16	,,	,,
,,	,,	,,	·78	·40	·51	15	,,	,,
,,	,,	,,	·84	·45	·57	15	,,	Right side.
,,	,,	,,	·89	·49	·58	16	,,	,,
,,	,,	,,	·85	·50	·58	16	,,	,,
—	—	—	·84	·45	·56	16	,,	Average for preceding ½-dozen scales.
10·80 cm. = 4·25 in.	8·33	Oct. 2, 1890	·79	·37	·51	14	– 1	Left side.
,,	,,	,,	·78	·45	·52	15	,,	,,
,,	,,	,,	·85	·49	·58	15	,,	,,
,,	,,	,,	·80	·47	·56	16	,,	Right side.
,,	,,	,,	·85	·48	·55	15	,,	,,
,,	,,	,	·88	·54	·61	15	,,	,,
—	—	—	·825	·466	·55	15	,,	Average for preceding ½-dozen scales.

11 cm. = 4·33 in.	9·35	Oct. 2, 1890	1	·48	·67	16	−1	Left side.
,,	,,	,,	·93	·44	·675	16	,,	,,
,,	,,	,,	·97	·44	·69	14	,,	,,
,,	,,	,,	·89	·40	·63	15	,,	Right side.
,,	,,	,,	·95	·43	·61	15	,,	,,
,,	,,	,,	·88	·42	·57	15	,,	,,
—	—	—	·936	·44	·641	15	,,	Average for preceding ½-dozen scales, all from same fish.
11·75 cm. = 4·62 in.	12·20	Dec. 4, 1889	·81	·40	·56	19	,,	Right side.
,,	,,	,,	·75	·45	·52	17	,,	,,
,,	,,	,,	·77	·43	·52	17	,,	,,
,,	,,	,,	·86	·37	·63	18	,,	Left side.
,,	,,	,,	·84	·40	·58	19	,,	,,
,,	,,	,,	·92	·53	·65	19	,,	,,
—	—	—	·83	·43	·58	18	,,	Average for preceding ½-dozen scales, all from same fish. A few scales from this fish were in a disintegrated condition.

FISH.			SCALES.					YEAR I.		
Length in cm.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B^n in mm.	No. of lines in A B^n	No. of rings.	Total length in mm.	Length of A B^1 in mm.	No. of lines in A B^1
28·5 = 11·22 in.	Not ascertained.	End of Oct. or begin. of Nov.	2·20	1·30	1·75	49	−2	1·30	·85	29
,,	,,	,,	2·40	1·30	1·71	46	,,	1·22	·89	26
,,	,,	,,	2·53	1·40	1·70	48	,,	1·30	·90	29
,,	,,	,,	2·92	1·50	1·81	49	,,	1·40	·93	29
,,	,,	,,	2·68	1·30	1·72	49	,,	1·27	·87	28
,,	,,	,,	2·74	1·35	1·76	48	,,	1·25	·87	29
,,	,,	,,	2·72	1·58	1·75	48	,,	1·30	·90	28
,,	,,	,,	2·51	1·26	1·78	49	,,	1·33	·93	29
—	—	—	2·58	1·37	1·75	48	,,	1·29	·89	28
35·5 = 13·97 in.	530	July 4, 1901	3·28	1·40	2·32	57	2+	·78	·52	24
,,	,,	,,	2·40	1·25	1·63	53	,,	·70	·46	20
,,	,,	,,	3·17	1·58	2·05	60	,,	·91	·59	24
,,	,,	,,	3·07	1·67	1·90	59	,,	·85	·54	23
,,	,,	,,	2·99	1·43	1·81	60	,,	·88	·56	23
,,	,,	,,	3·30	1·72	2·25	63	,,	·94	·67	24
,,	,,	,,	3·09	1·06	2·30	58	,,	·82	·65	24
,,	,,	,,	3·13	1·66	2·00	55	,,	·88	·57	20
—	—	—	3·05	1·47	2·03	58	,,	·85	·57	23
38·6 = 15·19 in.	535	June 18, 1901	2·37	·95	2·21	47	2+	·7	·57	12
,,	,,	,,	2·63	·74	2·34	48	,,	·68	·55	15
,,	,,	,,	2·42	·75	2·32	50	,,	·72	·59	16
,,	,,	,,	2·17	·87	1·94	50	,,	·66	·53	16
,,	,,	,,	2·29	·65	2·07	46	,,	·54	·41	16
,,	,,	,,	2·91	·87	2·74	49	,,	·62	·49	14
—	—	—	2·47	·81	2·27	48	,,	·65	·52	15
38·6 = 15·19 in.	535	June 18, 1901	3·58	1·53	2·22	65	2+	·91	·68	25
,,	,,	,,	3·23	1·45	2·21	59	,,	·84	·61	23
,,	,,	,,	3·30	1·75	2·06	59	,,	·90	·64	23
,,	,,	,,	3·90	1·50	2·51	63	,,	·95	·66	25
,,	,,	,,	3·50	1·69	2·29	61	,,	·88	·65	24
,,	,,	,,	4·02	1·73	2·52	62	,,	1·00	·70	25
—	—	—	3·92	1·61	2·30	62	,,	·91	·66	24
38·6 = 15·19 in.	535	June 18, 1901	4·08	1·84	2·44	70	2+	1·21	·83	28
,,	,,	,,	3·96	2·00	2·14	64	,,	1·19	·69	27
,,	,,	,,	3·89	2·00	2·38	68	,,	1·15	·84	28
,,	,,	,,	4·03	1·83	2·38	71	,,	1·12	·75	29
,,	,,	,,	3·88	1·84	2·30	64	,,	1·15	·80	29
,,	,,	,,	4·09	2·40	2·45	71	,,	1·20	·88	30
—	—	—	3·99	1·99	2·35	68	,,	1·17	·80	29
38·6 = 15·19 in.	535	June 18, 1901	3·85	1·87	2·37	69	2+	1·22	·86	32
,,	,,	,,	3·81	1·75	2·49	68	,,	1·22	·90	29
,,	,,	,,	4·33	1·95	2·64	72	,,	1·33	·91	32
,,	,,	,,	4·09	1·72	2·59	73	,,	1·30	·97	31

YEAR II.		YEAR III.		REMARKS.
Length of $B^1 B^2$ in mm.	No. of lines in $B^1 B^2$	Length of $B^2 B^n$ in mm.	No. of excentric lines	
·86	20	...	...	
·82	20	...	...	
·82	19	...	...	
·88	20	...	...	
·85	21	...	...	
·89	19	...	...	
·85	20	...	...	
·85	20	...	...	
·85	20	...	...	Average for preceding 8 scales, all from same fish.
1·00	28	·80	5	Right side.
·95	28	·22	5	,,
1·16	30	·30	6	,,
1·08	30	·28	6	,,
1·07	31	·18	6	Left side.
1·28	33	·30	6	,,
1·35	29	·30	5	,,
1·20	29	·25	6	,,
1·14	30	·34	6	Average for preceding 8 scales, all from same fish.
				The following 24 measurements have been made for purposes of comparison of scales from four different regions of the body in an older fish.
1·2	30	·17	5	Scale from left side of body, posterior to eye.
1·6	28	·22	5	
1·3	29	·25	5	
1·15	28	·22	6	
1·40	27	·25	6	
1·17	28	·32	7	
1·30	28	·24	6	Average for preceding ½-dozen scales.
1·12	32	·43	8	Scales from left side of body, median region of flanks, viz. proximity of pectoral fin.
1·00	30	·33	6	
1·10	31	·34	6	
1·40	31	·45	8	
1·38	31	·26	6	
1·50	30	·32	7	
1·25	31	·36	7	Average for preceding ½-dozen scales.
1·28	34	·33	8	Scales from left side of body laterally, vertically beneath second dorsal fin.
1·14	30	·31	7	
1·24	35	·30	5	
1·28	36	·35	6	
1·20	30	·30	5	
1·17	33	·40	8	
1·22	33	·33	7	Average for preceding ½-dozen scales.
1·26	31	·25	6	Scales from left side of body, vertically beneath third dorsal fin.
1·27	34	·32	5	
1·37	34	·36	6	
1·28	36	·34	6	
1·17	34	·37	5	

FISH.			SCALES.					YEAR I.		
Length in cm.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B^n in mm.	No. of lines in A B^n.	No. of rings.	Total length in mm.	Length of A B^1 in mm.	No. of lines in A B^1.
44·40 = 17½ in.	721·01	Apl. 30, 1901	3·76	2·06	2·35	69	3 +	·77	·54	19
,,	,,	,,	4·43	2·25	2·61	73	,,	·80	·58	22
,,	,,	,,	4·06	2·35	2·28	73	,,	·81	·55	22
,,	,,	,,	3·80	1·97	2·23	68	,,	·83	·51	21
—	—	—	4·01	2·16	2·37	71	,,	·80	·55	21
60 = 23·62 in.	1922·70	Apl. 30, 1901	4·99	2·75	3·18	90	4 +	·86	·65	20
,,	,,	,,	4·40	2·65	2·53	80	,,	·89	·64	25
,,	,,	,,	6·29	3·40	3·26	93	,,	1·21	·69	24
,,	,,	,,	6·53	3·43	3·51	102	,,	1·50	·73	26
—	—	—	5·55	3·06	3·12	91	,,	1·12	·68	24

FISH.			SCALES.					YEAR I.			YEAR II.	
Length in cm.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B^n in mm.	No. of lines in A B^n.	No. of rings.	Total length in mm.	Length of A B^1 in mm.	No. of lines in A B^1.	Length of B^1 B^2 in mm.	No. of lines in B^1 B^2.
83·82 = 33 in.	4184·70	June 13, 1901	8·49	4·35	5·09 ?	119	8 +	1·21	·76	26	1·22	25

N.B.—All the scales of this fish which were examined were seen to be more or less disintegrated. The measurements above were taken from one of the least disintegrated scales; but on account of the fact that many of the excentric lines had disappeared in the median plane (A B^n), the measurements interrogated, and the excentric lines in connection

YEAR II.		YEAR III.		YEAR IV.		YEAR V.		REMARKS.
Length of $B^1 B^2$ in mm.	No. of lines in $B^1 B^2$.	Length of $B^2 B^3$ in mm.	No. of lines in $B^2 B^3$.	Length of $B^3 B^4$ in mm.	No. of ex-centric lines.	Length of $B^4 B^5$ in mm.	No. of ex-centric lines in $B^4 B^5$.	
1·23	30	·52	18	·06	2	...	...	
1·28	30	·67	19	·08	2	...	...	
1·09	30	·56	19	·08	2	...	...	
1·06	27	·57	17	·09	3	...	...	
1·17	29	·58	18	·08	2	...	...	Average for preceding 4 scales.
1·00	28	·66	17	·67	19	·20	6	Several scales were disintegrated.
·80	22	·45	12	·54	18	·10	3	
·90	25	·82	20	·75	22	·10	2	
·95	24	·85	23	·85	27	·13	2	
·91	25	·70	18	·70	22	·13	3	Average for preceding 4 scales.

YEAR III.		YEAR IV.		YEAR V.		YEAR VI.		YEAR VII.		YEAR VIII.		YEAR IX.	
Length of $B^2 B^3$ in mm.	No. of ex-centric lines in $B^2 B^3$.	Length of $B^3 B^4$ in mm.	No. of ex-centric lines in $B^3 B^4$.	Length of $B^4 B^5$ in mm.	No. of ex-centric lines in $B^4 B^5$.	Length of $B^5 B^6$ in mm.	No. of ex-centric lines in $B^5 B^6$.	Length of $B^6 B^7$ in mm.	No. of ex-centric lines in $B^5 B^6$.	Length of $B^7 B^8$ in mm.	No. of ex-centric lines in $B^7 B^8$.	Length of $B^8 B^9$ in mm.	No. of ex-centric lines in $B^8 B^9$.
·35 ?	12	·37 ?	12	·42 ?	11	·41 ?	9	·51 !	11	·40 ?	10	·20 ?	3

therewith, were taken in a more lateral direction. At the same time the scale as observed laterally showed fairly conclusively *eight annual rings* plus a few excentric lines, evidently the growth of the early summer of 1901.

along with other results, with special reference to annual rings and lines of growth. It may serve to bring out some interesting points. The case of the fish with an asterisk, for example, 27·62 cm. in length, deserves notice. This fish only shows the following lines of growth: year I., 13; year II., 13; year III., 18.

We have evidently here to deal with a rapidly grown fish, and this fact has expressed itself in the formation of the scale, in the small number of lines of growth for the first and second year. The more intensive the growth the smaller the number of the lines of growth. To compare with this we might take the case of a slower growing pollack, 44·40 cm. The scale of such a pollack shows the following lines: year I., 21; year II., 29; year III., 18; year IV., 2. It is probable that in the first case the fish grew quickly in years I. and II., and in year III. about the normal.

SUMMARY OF EXAMINATION OF POLLACK SCALES,

With Special Reference to the Annual Rings and Lines of Growth.

Length of fish. cm.	Length of fish. inches.	Weight in grms.	Date of capture.	No. of ann. rings.	Average number of lines of growth (excentric lines) in years. 1	2	3	4	5	6	7	8	9	Notes.
2·5	nrly. 1·0	40	May	– 1	0	–	–	–	–	–	–	–	–	About 6 weeks old.
4·4	1·73	64	July	,,	2	–	–	–	–	–	–	–	–	,, 3 months old.
4·8	1·88	78	,,	,,	2	–	–	–	–	–	–	–	–	,, 3 ,,
5·4	2·12	1·08	,,	,,	2–3	–	–	–	–	–	–	–	–	†,, 3 ,,
5·9	2·32	1·45	,,	,,	4	–	–	–	–	–	–	–	–	,, 3 ,,
6·1	2·40	1·67	,,	,,	3	–	–	–	–	–	–	–	–	,, 3 ,,
6·4	2·51	1·95	,,	,,	5	–	–	–	–	–	–	–	–	,, 3 ,,
7·0	2·75	2·35	,,	,,	5	–	–	–	–	–	–	–	–	,, 3 ,,
9·15	3·60	6·60	Dec.	,,	16	–	–	–	–	–	–	–	–	,, 8 ,,
9·15	3·60	not taken	,,	,,	not taken	–	–	–	–	–	–	–	–	,, 8 ,,
9·25	3·64	6·22	Oct.	,,	15	–	–	–	–	–	–	–	–	,, 6 ,,
9·50	3·74	6·67	Dec.	,,	14	–	–	–	–	–	–	–	–	,, 8 ,,
9·65	3·79	5·45	Oct.	,,	14	–	–	–	–	–	–	–	–	,, 6 ,,
9·65	3·79	6·0	,,	,,	14	–	–	–	–	–	–	–	–	,, 6 ,,
9·85	3·87	9·25	Dec.	,,	21	–	–	–	–	–	–	–	–	,, 8 ,,
9·85	3·87	not taken	,,	,,	not taken	–	–	–	–	–	–	–	–	,, 8 ,,
10·0	3·93	9·45	,,	,,	20	–	–	–	–	–	–	–	–	‡,, 8 ,,
10·15	3·99	17·5	,,	,,	18	–	–	–	–	–	–	–	–	§,, 8 ,,
10·15	3·99	not taken	,,	,,	not taken	–	–	–	–	–	–	–	–	,, 8 ,,
10·20	4·01	8·20	,,	,,	17	–	–	–	–	–	–	–	–	,, 8 ,,
10·25	4·03	8·92	Oct.	,,	16	–	–	–	–	–	–	–	–	,, 6 ,,
10·35	4·07	8·30	,,	,,	16	–	–	–	–	–	–	–	–	,, 6 ,,
10·45	4·11	8·45	,,	,,	16	–	–	–	–	–	–	–	–	,, 6 ,,
10·55	4·15	8·10	,,	,,	15	–	–	–	–	–	–	–	–	,, 6 ,,
10·75	4·23	6·95	,,	,,	16	–	–	–	–	–	–	–	–	,, 6 ,,
10·80	4·25	8·33	,,	,,	15	–	–	–	–	–	–	–	–	,, 6 ,,
11·0	4·33	9·35	,,	,,	15	–	–	–	–	–	–	–	–	,, 6 ,,
11·75	4·62	12·20	Dec.	,,	18	–	–	–	–	–	–	–	–	‖,, 6 ,,
11·75	4·62	not taken	,,	,,	not taken	–	–	–	–	–	–	–	–	,, 8 ,,
14·60	5·75	,,	Sept.	,,	20	–	–	–	–	–	–	–	–	,, 5 ,,
14·92	5·87	,,	,,	,,	20	–	–	–	–	–	–	–	–	,, 5 ,,

SUMMARY OF EXAMINATION OF POLLACK SCALES—*continued.*

Length of fish. cm.	inches.	Weight in grms.	Date of capture.	No. of ann. rings.	Average number of lines of growth (excentric lines) in years. 1	2	3	4	5	6	7	8	9	Notes.
15·24	6·0	not taken	April	1+	not taken		–	–	–	–	–	–	–	About 1 yr. 6 wks. old.
15·55	6·125	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
15·55	6·125	,,	Sept.	–1	19	–	–	–	–	–	–	–	–	,, 5 months old.
16·83	6·625	,,	May	1+	27	5	–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
16·83	6·625	,,	Sept.	... –1	22	–	–	–	–	–	–	–	–	,, 5 months old.
16·83	6·625	,,	,,	–1	20	–	–	–	–	–	–	–	–	,, 5 ,,
16·83	6·625	,,	,,	,,	24	–	–	–	–	–	–	–	–	,, 5 ,,
17·14	6·750	,,	,,	,,	20	–	–	–	–	–	–	–	–	,, 5 ,,
17·14	6·750	,,	May	1+	not taken		–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
17·46	6·875	,,	Sept.	–1	23	–	–	–	–	–	–	–	–	,, 5 months old.
17·46	6·875	,,	,,	,,	21	–	–	–	–	–	–	–	–	,, 5 ,,
17·46	6·875	,,	,,	,,	23	–	–	–	–	–	–	–	–	,, 5 ,,
17·46	6·875	40	April	1+	25	4	–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
17·78	7·0	not taken	,,	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
18·09	7·125	55	,,	,,	21	8	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
18·09	7·125	not taken	Sept.	–1	23	–	–	–	–	–	–	–	–	,, 5 months old.
18·66	7·37	55	April	1+	25	3	–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
18·66	7·37	not taken	Sept.	–1	24	–	–	–	–	–	–	–	–	,, 5 months old.
19·05	7·5	,,	,,	,,	23	–	–	–	–	–	–	–	–	,, 5 ,,
19·05	7·5	,,	,,	,,	26	–	–	–	–	–	–	–	–	,, 5 ,,
19·68	7·75	,,	April	1+	not taken		–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
19·68	7·75	,,	Sept.	–1	24	–	–	–	–	–	–	–	–	,, 5 months old.
20·0	7·87	65	April	1+	29	4	–	–	–	–	–	–	–	,, 1 yr. 6 wks. old.
20·0	7·87	75	,,	,,	26	5	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
20·63	8·12	80	,,	,,	25	5	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
20·63	8·12	not taken	May	,,	26	3	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
20·63	8·12	,,	April	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
20·95	8·25	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
21·27	8·37	,,	April	,,	,,		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
21·27	8·37	,,	May	,,	29	–	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
21·90	8·62	,,	April	,,	27	5	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
21·90	8·62	,,	,,	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
21·90	8·62	,,	May	,,	25	6	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
22·86	9·0	105	April	,,	24	8	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
23·49	9·25	100	,,	,,	28	6	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
23·81	9·37	115	,,	,,	25	7	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·13	9·5	115	,,	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·44	9·62	not taken	May	,,	28	5	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·44	9·62	,,	April	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·44	9·62	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·76	9·75	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
24·76	9·75	,,	May	,,	25	8	–	–	–	–	–	–	–	††,, 1 ,, 6 ,,
25·08	9·87	,,	,,	,,	23	4	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
25·08	9·87	,,	,,	,,	26	8	–	–	–	–	–	–	–	,, 1 ,, 6 ,,
25·08	9·87	,,	April	,,	not taken		–	–	–	–	–	–	–	,, 1 ,, 6 ,,
*27·62	10·87	175	,,	3	*13	*13	18	–	–	–	–	–	–	,, 3 years old.
28·5	11·22	not taken	Nov.	–2	28	20	–	–	–	–	–	–	–	,, 1 yr. 7 mths. old.
28·57	11·25	,,	April	2+	not taken		–	–	–	–	–	–	–	,, 2 yrs. 6 wks. old
28·57	11·25	,,	May	,,	18	24	2	–	–	–	–	–	–	,, 2 ,, 6 ,,
29·84	11·75	,,	April	,,	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
30·6	12·0	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·11	12·25	265	,,	2+6 l.g.	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·11	12·25	not taken	,,	,, ,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·11	12·25	,,	,,	2+4 ,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·11	12·25	,,	,,	2+8 ,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·11	12·25	,,	,,	,, ,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·75	12·50	,,	,,	2+1–2	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·75	12·50	,,	May	2	25	24	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·75	12·50	,,	April	2+	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
31·75	12·50	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,

* See text, p. 74. †† See Pl. I., Fig. 5.

SUMMARY OF EXAMINATION OF POLLACK SCALES—*continued.*

Length of fish. cm.	inches.	Weight in grms.	Date of capture.	No. of ann. rings.	Average number of lines of growth (excentric lines) in years. 1	2	3	4	5	6	7	8	9	Notes.
32·06	12·62	not taken	April	2+	not taken		–	–	–	–	–	–	–	About 2 yrs. 6 wks. old.
32·06	12·62	,,	May	,,	22	19	5	–	–	–	–	–	–	,, 2 ,, 6 ,,
32·38	12·75	,,	April	2+7 l.g.	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
32·38	12·75	,,	,,	,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
32·38	12·75	,,	,,	2+... ,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
32·38	12·75	,,	,,	2+4 ,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
32·75	12·89	315	Oct.	–3	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 mths.
33·02	13·0	not taken	April	2+4 l.g.	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 wks. old.
33·02	13·0	,,	,,	2+8 ,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	,,	,,	2+	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	325	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	not taken	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·02	13·0	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·65	13·25	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·65	13·25	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·65	13·25	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·65	13·25	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
33·97	13·37	315	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·29	13·50	not taken	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·29	13·50	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·29	13·50	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·61	13·62	,,	May	,,	22	21	5	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·61	13·62	,,	April	,,	–	–	–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	,,	,,	,,	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	370	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	not taken	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	,,	,,	2+9 l.g.	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	,,	,,	2+	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
34·92	13·75	,,	,,	2+4 l.g.	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·5	13·97	530	July	2+	23	30	6	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·56	14·0	not taken	April	2+	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·56	14·0	,,	,,	2+5 l.g.	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·87	14·12	,,	,,	2+	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·87	14·12	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·87	14·12	,,	May	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
35·87	14·12	,,	April	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
36·83	14·50	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
36·83	14·50	,,	,,	,,	,,		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
37·46	14·75	470	,,	,,	26	25	5	–	–	–	–	–	–	,, 2 ,, 6 ,,
38·6	15·19	535	June	,,	24	31	7	–	–	–	–	–	–	,, 2 ,, 6 ,,
38·73	15·25	not taken	April	,,	not taken		–	–	–	–	–	–	–	,, 2 ,, 6 ,,
*44·40	17·50	1922·70	,,	3+	21	29	18	2	–	–	–	–	–	,, 3 ,, 6 ,,
44·40	17·50	not taken	,,	,,	not taken		–	–	–	–	–	–	–	,, 3 ,, 6 ,,
45·72	18·0	,,	May	,,	,,		–	–	–	–	–	–	–	,, 3 ,, 6 ,,
48·26	19·0	,,	April	,,	,,		–	–	–	–	–	–	–	,, 3 ,, 6 ,,
48·26	19·0	,,	May	,,	20	29	21	3	–	–	–	–	–	,, 3 ,, 6 ,,
57·15	22·50	,,	,,	4+	not taken		–	–	–	–	–	–	–	,, 4 ,, 6 ,,
60·0	23·62	1922·70	April	,,	24	25	18	22	3	–	–	–	–	,, 4 ,, 6 ,,
60·32	23·75	not taken	,,	5+	not taken		–	–	–	–	–	–	–	,, 5 ,, 6 ,,
63·50	25·0	,,	May	6+7 10 l.g.	,,		–	–	–	–	–	–	–	,, 6 ,, 6 ,,
64·77	25·50	,,	April	5+	,,		–	–	–	–	–	–	–	,, 5 ,, 6 ,,
78·74	31·0	,,	Apl. or May	8+	,,		–	–	–	–	–	–	–	,, 8 ,, 6 ,,
80·01	31·50	not taken	April	7+	,,		–	–	–	–	–	–	–	,, 7 ,, 6 ,,
83·82	33·0	4184·70	June	8+	26	25	12	12	11	9	11	10	3	,, 8 ,, 3 mths.
96·52	38·0	not taken	April	10+	not taken		–	–	–	–	–	–	–	,, 10 ,, 6 wks. old.

* See text, p. 74.

The following two tables are summaries of the more detailed tables and of other results, giving the ages of a number of fish in a more convenient and concise form. The first of these tables may serve to bring out exceptions or variation, namely, that in some cases pollack of approximately the same size may be of a very different age.

The second of these tables is a more general one, and serves rather to bring out the more general facts as to the size of pollack in relation to age.

POLLACK.

No. taken.	Length of fish in cm.	Age of fish.
7	2–7	First summer.
21	9–11·75	,, winter.
2	14·60–14·92	,, summer (late).
3	14·92–15	Second spring.
1	15·55	First summer (late).
1	16·83	Second spring.
4	16·83–17	First summer (late).
1	17·14	Second spring.
3	17·46	First summer (late).
3	17–18	Second spring.
1	18·09	First summer (late).
1	18·66	Second spring.
4	18·–19	First summer (late).
24	19–25	Second spring.
1	27·62	Fourth ,,
1	28·5	Second winter.
19	28·–32	Third spring.
1	32·75	,, winter.
25	33·–34	,, spring.
1	35·5	,, summer.
9	35·–37	,, spring.
1	38·6	,, summer.
1	38·73	,, spring.
2	44·40	Fourth ,,
1	45·72	,, ,,
2	48·26	,, ,,
1	57·15	Fifth ,,
1	60·0	,, ,,
1	60·32	Sixth ,,
1	63·50	Seventh ,,
1	64·77	Sixth ,,
1	78·74	Ninth ,,
1	80·01	Eighth ,,
1	83·82	Ninth summer.
1	96·52	Eleventh spring.

POLLACK.

Summarised Table of Age.

Length of fish in cm.	Age of fish.
2–19	First summer
9–11·75	,, winter.
14·92–25	Second summer.
28·5	,, winter.
28·0–38·6	Third summer.
27·62–48·26	Fourth ,,
57·15–60·0	Fifth ,,
60·32–64·77	Sixth ,,
63·50	Seventh ,,
80·01	Eighth ,,
78·74–83·82	Ninth ,,
96·52	Eleventh ,,

NOTE.—Summer is here taken as from April to October, winter as from October to April.

The next table is a summary of averages from the more detailed tables to show, in a general way, the increase in the length and breadth of scales, at various ages of the fish. From these tables it would be an easy matter to calculate the approximate area of scales, as many of the pollack's scales are nearly elliptical in shape.

SUMMARISED TABLE

Showing Average surface size of Scales in the Pollack at various ages.

No. of fish.	Range of length in cm.	Range of weight in grms.	Month of capture.	Average length of scale in mm.	Average length of $A.B.^1$ and $A.B.^n$ in mm.	Average breadth of scales in mm.	Average lines of growth in years.								
							1	2	3	4	5	6	7	8	9
4	4·4–5·9	·64–1·45	July	·25	·15	·15	3	–	–	–	–	–	–	–	–
3	6·1–7·0	1·67–2·35	,,	·35	·21	·23	4	–	–	–	–	–	–	–	–
6	9·15–9·85	6·60–9·25	Oct.–Dec.	·70	·48	·40	16	–	–	–	–	–	–	–	–
9	10·0–10·80	6·95–9·45	,, ,,	·816	·565	·441	17	–	–	–	–	–	–	–	–
2	11·0–11·75	9·35–12·20	,, ,,	·883	·610	·44	17	–	–	–	–	–	–	–	–
					Length of $A.B.^n$										
1	28·5	not taken	Oct. or Nov.	2·58	1·75	1·37	28	20	–	–	–	–	–	–	–
2	35·5–38·6	530–535	June–July	3·49	2·17	1·54	24	31	7	–	–	–	–	–	–
1	44·40	721·01	April	4·01	2·37	2·16	21	29	18	2	–	–	–	–	–
1	60·0	1922·70	,,	5·55	3·12	3·06	24	25	18	22	3	–	–	–	–
1	83·82	4184·70	June	8·49	5·09	4·35	26	25	12	12	11	9	11	10	3

For purposes of comparison, I annex a short table of ages for the pollack from Cunningham's paper on the "Rate of Growth of some Sea Fishes" (*Journal of Marine Biological Association*, vol. ii., n.s., 1891–2).

GADUS POLLACHIUS, THE POLLACK.

Table from Cunningham's "Rate of Growth of some Sea Fishes" (*Journal of Marine Biological Association*, 1891–2).

Date of collection.	No. of specimens.	Length in cm.	Length in inches.	Calculated age.
April 3, 1890	22	2–2·4	·8–·95	3 to 6 weeks.
Oct. 2, 1890	10	9·7–11·2	3·8–4·4	7 months.
Dec. 4, 1889	4	9·3–11·8	3·7–4·7	9 ,,

The Poor Cod *(Gadus minutus)*.

Cunningham mentions the occurrence of over two hundred specimens less than three inches long in Whitsand Bay in the middle of June, and that they undoubtedly developed from ova shed the preceding spring. He calculates the age of these at about three months.

TABULAR RESULTS OF EXAMINATION OF SCALES OF POOR COD, *Gadus minutus*.

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of $A B^1$ in mm.	No. of excentric lines.	No. of annual rings.	NOTES.
3·3 cm. = 1·29 in.	·27	June 3, 1889	·23	·13	·12	0	−1	Locality of capture, Whitsand Bay.
3·9 cm. = 1·53 in.	·48	June 3, 1889	·21	·15	·12	2	0	From Whitsand Bay.
,,	,,	,,	·20	·15	·10	2	0	,,
—	—	—	·21	·15	·11	2	0	Average.
4·3 cm. = 1·69 in.	·55	June 17, 1889	·31	·22	·18	2	0	From Whitsand Bay; also numerous minute scales without any excentric lines.
4·4 cm. = 1·73 in.	·65	June 17, 1889	·50	·40	·28	6	0	From Whitsand Bay.
,,	,,	,,	·30	·27	·19	4	0	,,
,,	,,	,,	·47	·35	·25	5	0	,,
—	—	—	·42	·34	·24	5	0	Average.
4·7 cm. = 1·85 in.	·73	June 3, 1889	·34	·26	·19	3	0	From Whitsand Bay.
,,	,,	,,	·34	·20	·36	3	0	,,
—	—	—	·34	·23	·28	3	0	Average.
4·7 cm. = 1·85 in.	·72	June 3, 1889	·29	·29	·16	3	0	Fish captured 3 miles from Rame Head.
,,	,,	,,	·23	·26	·12	2	0	
—	—	—	·26	·28	·14	3	0	Average.
4·8 cm. = 1·88 in.	1·22	June 17, 1889	·58	·55	·33	7	0	From Whitsand Bay.
,,	,,	,,	·53	·38	·32	6	0	
,,	,,	,,	·55	·55	·35	7	0	
,,	,,	,,	·62	·51	·31	7	0	
—	—	—	·57	·50	·33	7	0	Average.

RESULTS OF EXAMINATION OF SCALES OF POOR COD—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of AB[1] in mm.	No. of excentric lines.	No. of annual rings.	NOTES.
4·8 cm. = 1·88 in.	·8	June 17, 1889	·32	·39	·19	6	0	From Whitsand Bay.
,,	,,	,,	·34	·35	·21	5	0	,,
—	—	—	·33	·37	·20	6	0	Average.
5·0 cm. = 1·96 in.	1·07	June 3, 1889	·55	·50	·33	7	0	From Whitsand Bay.
,,	,,	,,	·45	·49	·27	5	0	,,
—	—	—	·50	·50	·30	6	0	Average.
5·2 cm. = 2·04 in.	1·09	June 17, 1889	·22	·21	·14	4	0	Same lot of fish; few scales remaining on fish.
,,	,,	,,	·37	·29	·19	6	0	
,,	,,	,,	·38	·25	·23	6	0	
—	—	—	·32	·38	.28	8	0	Average.
5·5 cm. = 2·16 in.	1·27	June 17, 1889	·32	·25	·18	3	0	Same lot of fish; from Whitsand Bay.
,,	,,	,,	·33	·29	·21	3	0	
—	—	—	·33	·27	·20	3	0	Average.
5·6 cm. = 2·20 in.	1·32	June 17, 1889	·58	·49	·30	7	0	From Whitsand Bay.
,,	,,	,,	·63	·50	·38	7	0	,,
—	—	—	·61	·50	·34	7	0	Average.
5·6 cm. = 2·20 in.	1·30	June 17, 1889	·67	·68	·35	8	0	From Whitsand Bay.
,,	,,	,,	·71	·65	·41	9	0	,,
—	—	—	·69	·67	·38	9	0	Average.
5·7 cm. = 2·24 in.	1·35	June 17, 1889	·61	·61	·38	7	0	From Whitsand Bay.
,,	,,	,,	·47	·48	·37	6	0	,,
—	—	—	·54	·55	·38	7	0	Average.
5·7 cm. = 2·24 in.	1·32	June 17, 1889	·77	·62	·35	7	0	From Whitsand Bay.
,,	,,	,,	·509	·508	·35	7	0	,,
—	—	—	·640	·564	·35	7	0	Average.
5·8 cm. = 2·28 in.	1·40	June 17, 1889	·75	·65	·36	7	0	From Whitsand Bay, fish labelled being 2–3 months old.
5·8 cm. = 2·28 in.	1·30	June 17, 1889	·59	·42	·30	7	0	From Whitsand Bay.
,,	,,	,,	·63	·45	·32	8	0	,,
—	—	—	·61	·44	·31	8	0	Average.
5·8 cm. = 2·28 in.	1·75	June 17, 1889	·31	·23	·29	3	0	All from same fish; from Whitsand Bay.
,,	,,	,,	·38	29	·22	4	0	
,,	,,	,,	·38	·33	·23	4	0	
,,	,,	,,	·39	·32	·24	5	0	
—	—	—	·37	·29	·25	4	0	Average.

RESULTS OF EXAMINATION OF SCALES OF POOR COD—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B[1] in mm.	No. of excentric lines.	No. of annual rings.	NOTES.
5·9 cm. = 2·32 in.	1·55	June 17, 1889	·56	·38	·36	7	0	Same lot of fish ; from Whitsand Bay.
,,	,,	,,	·45	·52	·27	7	0	
,,	,,	,,	·65	·50	·35	7	0	
,,	,,	,,	·51	·38	·30	7	0	
—	—	—	·54	·45	·32	7	0	Average for preceding 4 scales, all from same fish.
5·9 cm. = 2·32 in.	1·65	June 17, 1889	·68	·60	·36	9	0	From Whitsand Bay.
,,	,,	,,	·67	·70	·37	9	0	,,
—	—	—	·68	·65	·37	9	0	Average.
6·0 cm. = 2·36 in.	1·59	June 17, 1889	·66	·40	·38	7	0	From Whitsand Bay.
,,	,,	,,	·54	·43	·32	6	0	,,
—	—	—	·60	·42	.35	7	0	Average.
6·0 cm. = 2·36 in.	1·65	June 17, 1889	·50	·39	·32	8	0	From Whitsand Bay.
,,	,,	,,	·55	·44	·29	6	0	,,
—	—	—	·53	·42	·31	7	0	Average.
6·1 cm. = 2·40 in.	1·77	June 17, 1889	·59	·53	·38	6	0	From Whitsand Bay.
,,	,,	,,	·72	·51	·41	9	0	,,
—	—	—	·66	·52	·39	8	0	Average.
6·1 cm. = 2·40 in.	1·92	June 17, 1889	·73	·71	·43	9	0	From Whitsand Bay.
,,	,,	,,	·65	·65	·36	8	0	,,
—	—	—	·69	·68	·40	9	0	Average.
6·3 cm. = 2·48 in.	2·3	June 17, 1889	·72	·72	·38	9	0	From Whitsand Bay.
,,	,,	,,	·74	·79	·43	10	0	,,
—	—	—	·73	·76	·81	10	0	Average.
6·5 cm. = 2·55 in.	2·22	June 17, 1889	·81	·79	·65	9	0	From Whitsand Bay; measurements not very accurate.
,,	,,	,,	·89	·78	·68	10	0	
,,	,,	,,	·98	1·15	·70	10	0	
,,	,,	,,	·92	·78	·70	8	0	
—	—	—	·90	·88	·68	9	0	Average.
6·8 cm. = 2·67 in.	2·57	June 17, 1889	·49	·35	·30	5	0	Same lot of fish.
,,	,,	,,	·75	·59	·40	8	0	
,,	,,	,,	·75	·69	·35	9	0	
,,	,,	,,	·72	·71	·40	10	0	
—	—	—	·68	·59	·36	8	0	Average.
10 cm. = 3·93 in.	8+	Late winter or early spring 1901	1·50	1·25	·90	22	1	N.B.—The weight and date of capture are in this case uncertain.
,,	,,	,,	1·70	1·55	·93	19	1+9 c.l.	
,,	,,	,,	1·67	1·20	·95	22	1	
,,	,,	,,	1·50	1·17	·93	24	1	
,,	,,	,,	1·43	1·16	·85	26	1	
,,	,,	,,	1·30	1·00	·75	23	1	
,,	,,	,,	1·36	1·00	·75	23	1	
—	—	—	1·49	1·19	·86	23	1+1–2	Average for above 7 scales, all from same fish.

RESULTS OF EXAMINATION OF

FISH.			SCALES.				
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A Bn in mm.	No. of excentric lines.	No. of annual rings.
11·5 cm. = 4·54 in.	14·8	July 9, 1901	1·97	1·68	1·09	40	1 + 10 c.l.
11·70 cm. = 4·60 in.	15·75	July 9, 1901	1·99	1·80	1·00	42	1 + 9 c.l.
,,	,,	,,	1·90	1·68	1·09	33	1 + 6 c.l.
—	—	—	1·95	1·74	1·05	38	1 + 8 c.l.
12·5 cm. = 4·92 in.	16·8	July 9, 1901	1·57	1·40	·94	36	1 + 10 c.l.
,,	,,	,,	1·61	1·38	·85	30	1 + 8 c.l.
,,	,,	,,	1·56	1·17	1·12	27	1 + 8 c.l.
,,	,,	,,	1·74	1·43	1·14	34	1 + 9 c.l.
—	—	—	1·62	1·35	1·01	32	1 + 9 c.l.
13 cm. = 5·11 in.	18·4	July 9, 1901	2·09	1·90	1·19	43	1 + 12 c.l.
,,	,,	,,	2·22	1·88	1·35	38	1 + 10 c.l.
—	—	—	2·16	1·89	1·27	41	1 + 11 c.l.
13 cm. = 5·11 in.	19·5	July 9, 1901	2·18	1·85	1·23	43	1 + 11 c.l.
,,	,,	,,	2·31	1·91	1·18	42	1 + 11 c.l.
,,	,,	,,	2·37	1·90	1·23	42	1 + 10 c.l.
,,	,,	,,	2·03	1·70	1·10	40	1 + 10 c.l.
—	—	—	2·22	1·84	1·19	42	1 + 11 c.l.
13·5 cm. = 5·31 in.	24·5	July 9, 1901	2·22	2·00	1·27	44	1 + 13 c.l.
,,	,,	,,	2·14	2·00	1·19	42	1 + 10 c.l.
,,	,,	,,	1·99	1·87	1·12	45	1 + 13 c.l.
,,	,,	,,	2·21	2·00	1·20	45	1 + 13 c.l.
—	—	—	2·14	1·97	1·20	44	1 + 12 c.l.
14·3 cm. = 5·62 in.	24·9	July 9, 1901	1·57	1·30	·98	32	1 + 10
,,	,,	,,	2·02	1·72	1·22	38	1 + 10
,,	,,	,,	2·00	1·95	1·26	43	1 + 9
,,	,,	,,	2·34	2·00	1·32	47	1 + 11
—	—	—	1·98	1·74	1·20	40	1 + 10

FISH.			SCALES.				
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A Bn in mm.	No. of excentric lines.	No. of annual rings.
18·8 cm. = 7·40 in.	53·15	not known	3·00	2·77	1·95	70	2 + c.l.
,,	,,	,,	4·35	1·67	1·73	51	2 + c.l.
—	—	—	3·68	2·22	1·84	61	2 + c l.
19·5 cm. = 7·67 in.	55	not known	2·52	2·30	1·52	52	2 + c.l.
,,	,,	,,	2·45	1·90	1·53	57	2 + c.l.
—	—	—	2·49	2·10	1·53	55	2 + c.l.

SCALES OF POOR COD—*continued.*

YEAR I.			YEAR II.		REMARKS.
Total length year's growth in mm.	Length of AB^1 in mm.	No. of excentric lines.	Length of B^1B^2 in mm.	No. of excentric lines.	
1·35	·80	30	·29	10	Few scales on this fish, and those mostly disintegrated.
1·64	·78	33	·22	9	Several scales disintegrated.
1·54	·89	27	·20	6	
1·59	·84	30	·21	8	Average.
1·20	·72	26	·22	10	
1·18	·77	22	·20	8	
1·20	·87	19	·25	8	
1·30	·90	25	·24	9	
1·22	·82	23	·23	9	Average for preceding 4 scales, all from same fish.
1·40	·85	31	·34	12	
1·50	1·00	28	·35	10	
1·45	·93	30	·35	11	Average.
1·50	·90	32	·33	11	
1·55	·86	31	·32	11	
1·64	·92	31	·31	10	
1·40	·80	30	·30	10	
1·52	·87	31	·32	11	Average for preceding 4 scales, all from same fish.
1·42	·84	32	·43	12	A number of disintegrated scales.
1·40	·85	32	·34	10	,, ,,
1·22	·75	32	·37	13	,, ,,
1·42	·85	32	·35	13	,, ,,
1·37	·82	32	·37	12	Average for preceding 4 scales, all from same fish.
1·05	·70	22	·28	10	
1·43	·90	28	·32	10	
1·41	1·00	34	·26	9	
1·70	·98	36	·34	11	
1·40	·90	30	·30	10	Average for preceding 4 scales, all from same fish.

YEAR I.			YEAR II.		YEAR III.		REMARKS.
Total length year's growth in mm.	Length of AB^1 in mm.	No. of excentric lines.	Length of B^1B^2 in mm.	No. of excentric lines.	Length of B^2B^3 in mm.	No. of excentric lines.	
1·48	·90	28	·78	29	·27	13	Scale from position very slightly posterior to pectoral fin.
1·50	·65	23	·82	20	·26	8	This scale very different from preceding, [and has been taken from [nearer the lateral line.
1·49	·78	26	·80	25	·27	11	Average.
·85	·64	17	·56	19	·32	16	The above statistics are not of much detailed value, as the date of capture
1·10	·70	20	·52	22	·31	15	of these two fishes is not known.
·98	·67	19	·54	21	·32	16	Average.

Summary of Examination of Scales of Poor Cod.

Length of fish.		Weight in grms.	Date of capture.	No. of annual rings.	No. of lines of growth (excentric lines) in years			Approximate age.
cm.	in.				1	2	3	
3·3	1·29	·27	June	−1	0	—	—	3 months.
3·9	1·53	·48	,,	,,	2	—	—	,,
4·3	1·69	·55	,,	,,	2	—	—	,,
4·4	1·73	·65	,,	,,	5	—	—	,,
4·7	1·85	·73	,,	,,	3	—	—	,,
4·7	1·85	·72	,,	,,	3	—	—	,,
4·8	1·88	1·22	,,	,,	7	—	—	,,
4·8	1·88	·8	,,	,,	6	—	—	,,
5·0	1·96	1·07	,,	,,	6	—	—	,,
5·2	2·04	1·09	,,	,,	8	—	—	,,
5·5	2·16	1·27	,,	,,	3	—	—	,,
5·6	2·20	1·45	,,	,,	6	—	—	,,
5·6	2·20	1·32	,,	,,	7	—	—	,,
5·6	2·20	1·30	,,	,,	9	—	—	,,
5·7	2·24	1·35	,,	,,	7	—	—	,,
5·7	2·24	1·32	,,	,,	7	—	—	,,
5·8	2·28	1·40	,,	,,	7	—	—	,,
5·8	2·28	1·30	,,	,,	8	—	—	,,
5·8	2·28	1·75	,,	,,	4	—	—	,,
5·9	2·32	1·55	,,	,,	7	—	—	,,
5·9	2·32	1·65	,,	,,	9	—	—	,,
6·0	2·36	1·59	,,	,,	7	—	—	,,
6·0	2·36	1·65	,,	,,	7	—	—	,,
6·1	2·40	1·77	,,	,,	8	—	—	,,
6·1	2·40	1·92	,,	,,	9	—	—	,,
6·3	2·48	2·3	,,	,,	10	—	—	,,
6·5	2·55	2·22	,,	,,	9	—	—	,,
6·8	2·67	2·57	,,	,,	8	—	—	,,
10·0	3·93	8·0	late winter or early spring.	1+1...2 l.g.	23	—	—	1 year 1 month (?)
10·16	4·0	4·0	October	−1	not taken			7 months.
11·5	4·54	14·8	July	1+	30	10	—	1 year 3–4 months.
11·70	4·60	15·75	,,	1+	30	8	—	,, ,,
12·38	4·87	not taken	February	−1	not taken			11 months.
12·50	4·92	16·8	July	1+	23	9	—	1 year 3–4 months.
13·0	5·11	18·4	,,	1+	30	11	—	,, ,,
13·0	5·11	19·5	,,	1+	31	11	—	,, ,,
13·0	5·11	not taken	February	−1	not taken			11 months.
13·33	5·25	,,	January	−2	,,			1 year 10 months.
13·50	5·31	24·5	July	1+	32	12	—	1 year 3–4 months.
13·65	5·37	not taken	May	1+	—	—	—	1 year 2 months.
14·3	5·62	24·9	July	1+	30	10	—	1 year 3–4 months.
14·3	5·62	not taken	,,	1+	not taken			,, ,,
14·60	5·75	25·0	May	1+	,,			1 year 2 months.
15·55	6·12	not taken	February	−1	,,			11 months.
15·87	6·25	26·0	April	2+	,,			2 years 1 month.
17·14	6·75	35·5	,,	2+	,,			,, ,,
17·78	7·0	not taken	October	−3	,,			2 years 7 months.
18·09	7·12	63·0	May	2+	,,			2 years 2 months.
18·8	7·40	53·15	not known	2+	26	25	11	2 years 3–4 months.
19·05	7·50	not taken	,,	−3	not taken			Under 3 years.
19·36	7·62	48·5	April	3+	,,			3 years 1 month.
19·45	7·66	not taken	not known	−3	,,			Under 3 years.
19·5	7·67	55·0	,,	3	19	21	16	About 3 years.
19·5	7·67	55·0	,,	−3	not taken			Under 3 years.
19·68	7·75	not taken	,,	−3	,,			,, ,,
20·32	8·0	51·5	April	2+	,,			2 years 1 month.
22·22	8·75	110·0	February	−2	—	—	—	1 year 11 months.
23·75	9·35	not taken	,,	−3	—	—	—	2 years 11 months.

Summarised Table

Showing Average surface size of Scales in the Poor Cod at various stages.

No. of fish.	Range of length in cm.	Range of weight in grms.	Month of capture.	Average length of scale in mm.	Average length of AB^1 or AB^n in mm.	Average breadth of scale in mm.	Average lines of growth in years. 1	2	3
1	3·3	·27	June	·23	·12	·13	0	–	–
7	3·9–4·8	·48–·80	,,	·35	·21	·30	4	–	–
13	5·0–5·9	1·07–1·65	,,	·56	·34	·50	7	–	–
7	6·0–6·8	1·59–2·57	,,	·68	·47	·61	8	–	–
1	10·0	8	uncertain, late winter or early spring.	1·49	·86	1·19	23	–	–
					AB^n				
2	11·5–11·70	14·8–15·75	July	1·92	1·07	1·71	30	9	–
5	12·5–14·3	16·8–24·9	,,	2·02	1·18	1·76	29	11	–
1	18·8	53·15	not known	3·68	1·84	2·22	26	25	11
1	19·5	55	,,	2·49	1·53	2·10	19	21	16

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POOR COD.—*Summary of Age.*

Length of fish in cm.	Age of fish.
3–10	First summer.
10·16–15·55	,, winter.
11·50–14·60	Second summer.
13·33–22·22	,, winter.
15·87–20·32	Third summer.
17·78–23·75	,, winter.
19·36–......	Fourth summer.

NOTE.—The detailed table shows more clearly how variable in size fishes of the same age may be.

GADUS MINUTUS, THE POOR COD.

Table from Cunningham's "Rate of Growth of some Sea Fishes" (Journal of Marine Biological Association, 1891–2).

Date of collection.	Number of specimens.	Length in cm.	Length in inches.	Calculated age.
May 28, 1890	12	2·8–4·3	1·1–1·7	8–12 weeks.
June 17, 1889	218	4·2–7·2	1·6–2·9	About 3 months.
July 9, 1891	6	11·5–16·2	4·5–6·4	1 year 3 ,,
April 19, 1891	7	14·3–19·0	5·6–7·5	2 years.
June 17, 1889	2	13·7–15·0	5·4–5·8	1 year 2 months.
,,	1	20·0	7·8	2 ,, 2 ,,

The Whiting *(Gadus merlangus)*.

According to Fulton, "the spawning season of the whiting extends from the beginning of March to the end of June or beginning of July, with its maximum about the end of April, and at the temperature of the water at that time the eggs will take about ten or twelve days to hatch."

"The bulk of the larval whitings may thus be regarded as beginning their independent pelagic life in the early part of May, at a length of about 3·5 mm. ($\frac{1}{7}$ inch)."

By the end of the summer they are, on an average, more than four inches in length. "The growth of the young whiting is very rapid."

According to Cunningham, the whiting at Plymouth spawn in February and March. In the middle of June they are about two inches in length, and he estimates their age at three or four months. In the middle of July they are two to three and a half inches in length, and he estimates their age at about four or five months.

Tabular Results of Examination of Scales of Whiting, *Gadus merlangus.*

Fish.			Scales.					
Length.	Weight in grms.	Date of capture.	Length in mm.	Maximum breadth in mm.	Length of A B¹.	No. of lines of growth.	No. of annual rings.	Notes.
5·4 cm. = 2·12 in.	1·12	June 17, 1889	·29	·23	·17	3	−1	Locality of capture, Whitsand Bay. These scales were taken from a part slightly posterior to the usual area.
,,	,,	,,	·33	·28	·22	4	,,	
,,	,,	,,	·30	·20	·16	3	,,	
,,	,,	,,	·40	·38	·24	4	,,	
,,	,,	,,	·33	·29	·17	3	,,	
—	—	—	·33	·28	·19	3	—	Average.
7·8 cm. = 3·07 in.	2·85	Oct. 25, 1892	·59	·37	·35	11	−1	From Cunningham's Grimsby collection, trawled off the Humber October 25, 1902.
,,	,,	,,	·60	·34	·32	11	,,	
,,	,,	,,	·62	·43	·39	11	,,	
,,	,,	,,	·56	·32	·35	11	,,	
,,	,,	,,	·50	·35	·30	10	,,	
,,	,,	,,	·66	·32	·38	9	,,	
—	—	—	·59	·36	·35	11	,,	Average for preceding ½-dozen scales, all from same fish.
8·2 cm. = 3·22 in.	3·47	Oct. 25, 1892	·69	·52	·38	10	−1	From Cunningham's Grimsby collection, s s. *Valertia* trawled off Humber, October 25, 1892.
,,	,,	,,	·62	·49	·30	9	,,	
,,	,,	,,	·64	·46	·35	10	,,	
,,	,,	,,	·52	·24	·28	8	,,	
,,	,,	,,	·72	·46	·37	9	,,	
,,	,,	,,	·61	·37	·34	9	,,	
—	—	—	·63	·42	·34	9	,,	Average for preceding ½-dozen scales, all from same fish.
8·4 cm. = 3·30 in.	3·44	Oct. 25, 1892	·56	·41	·30	9	−1	Same locality as last.
,,	,,	,,	·55	·43	·33	10	,,	
,,	,,	,,	·60	·44	·33	10	,,	
,,	,,	,,	·60	·47	·33	11	,,	
—	—	—	·58	·44	·32	10	,,	Average for preceding 4 scales, all from same fish.
9·8 cm = 3·85 in.	3·97	Oct. 25, 1892	·53	·41	·37	9	−1	From Cunningham's Grimsby collection; off the Humber, s.s. *Valertia.*
,,	,,	,,	·56	·55	·39	10	,,	
,,	,,	,,	·70	·37	·40	9	,,	
,,	,,	,,	·60	·49	·33	10	,,	
—	—	—	·60	·46	·37	10	,,	Average.
11 cm. = 4·33 in.	9	Nov. 4–16, 1901	·86	·60	·52	20	−1	From Teignmouth Bay.
,,	,,	,,	·70	·47	·42	16	,,	,,
,,	,,	,,	·76	·55	·49	18	,,	,,
,,	,,	,,	·84	·58	·52	20	,,	,,
—	—	—	·79	·55	·49	19	,,	Average.

TABULAR RESULTS OF EXAMINATION OF SCALES OF WHITING—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Length in mm.	Maximum breadth in mm.	Length of A B1.	No. of lines of growth.	No. of annual rings.	NOTES.
11·5 cm. = 4·52 in.	9·09	Nov. 4–16, 1901	·64	·39	·40	11	– 1	From Teignmouth Bay.
,,	,,	,,	·74	·46	·46	15	,,	,,
,,	,,	,,	·66	·39	·41	16	,,	,,
,,	,,	,,	·75	·42	·42	16	,,	,,
,,	,,	,,	·74	·43	·47	17	,,	,,
,,	,,	,,	·67	·39	·41	16	,,	,,
—	—	—	·70	·41	·43	15	,,	Average for preceding ½-dozen scales, all from same fish.
11·90 cm. = 4·68 in.	10·15	Nov. 4–16, 1901	·80	·55	·51	17	– 1	This fish had few scales, some disintegrated, others of very small size, and, indeed, gave some hints of pathological conditions. Fish from same locality.
,,	,,	,,	·67	·40	·41	15	,,	
,,	,,	,,	·73	·43	·41	17	,,	
,,	,,	,,	·71	·48	·43	16	,,	
,,	,,	,,	·70	·49	·42	17	,,	
,,	,,	,,	·67	·41	·38	15	,,	
—	—	—	·71	·46	·43	16	,,	Average for preceding ½-dozen scales, all from same fish.
12·20 cm. = 4·80 in.	12·8	Nov. 4–16, 1901	·90	·69	·54	22	– 1	From same locality.
,,	,,	,,	1·00	·70	·60	22	,,	,,
,,	,,	,,	·98	·70	·56	24	,,	,,
,,	,,	,,	1·04	·67	·62	23	,,	,,
,,	,,	,,	·71	·48	·42	17	,,	,,
,,	,,	,,	·85	·58	·52	19	,,	,,
—	—	—	·91	·64	·54	21	,,	Average for preceding ½-dozen scales, all from same fish.
12·40 cm. = 4·88 in.	15·40	Nov. 4–16, 1901	·88	·60	·52	21	– 1	From same locality.
,,	,,	,,	·81	·57	·50	19	,,	,,
,,	,,	,,	·81	·55	·50	20	,,	,,
,,	,,	,,	·87	·58	·53	20	,,	,,
,,	,,	,,	·82	·59	·46	19	,,	,,
,,	,,	,,	·75	·55	·46	19	,,	,,
—	—	—	·82	·57	·49	20	,,	Average for preceding ½-dozen scales, all from same fish.
13 cm. = 5·11 in.	Fish damaged	Sept. 28, 1901	1·10	·73	·67	21	– 1	From Cattewater, Plymouth.
,,	,,	,,	·97	·62	·60	18	,,	,,
,,	,,	,,	1·00	·58	·60	20	,,	,,
,,	,,	,,	·92	·58	·54	18	,,	,,
—	—	—	1·00	·63	·60	19	,,	Average for preceding 4 scales, all from same fish.
13·65 cm. = 5·37 in.	17·4	Nov. 4–16, 1901	·81	·55	·50	17	– 1	From Teignmouth. The distinction between summer growth and winter growth is by no means clearly defined in the Whiting scales of this date; there are indications of a much greater winter growth than in the case of Pollack and Poor Cod.
,,	,,	,,	·76	·66	·48	17	,,	
,,	,,	,,	1·18	·64	·70	24	,,	
,,	,,	,,	1·06	·76	·63	23	,,	
—	—	—	·95	·65	·58	20	,,	Average for preceding 4 scales, all from same fish.
14·00 cm. = 5·51 in.	18·75	Nov. 4–16, 1901	1·12	·80	·63	24	– 1	From Teignmouth Bay.
,,	,,	,,	1·18	·92	·68	25	,,	,,
,,	,,	,,	1·07	·79	·59	21	,,	,,
,,	,,	,,	1·09	1·00	·67	26	,,	,,
—	—	—	1·12	·88	·64	24	,,	Average for preceding 4 scales, all from same fish.

TABULAR RESULTS OF EXAMINATION OF SCALES OF WHITING—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Length in mm.	Maximum breadth in mm.	Length of A B1.	No. of lines of growth.	No. of annual rings.	NOTES.
14·65 cm. = 5·76 in.	23·15	Sept. 28, 1901	1·27	·90	·80	24	– 1	From Cattewater, Plymouth.
,,	,,	,,	1·20	·78	·73	23	,,	,,
,,	,,	,,	1·10	·75	·70	23	,,	,,
,,	,,	,,	1·20	·77	·70	24	,,	,,
—	—	—	1·19	·80	·73	24	,,	Average for preceding 4 scales, all from same fish.
14·75 cm. = 5·80 in.	26·90	Nov. 4–16, 1901	·94	·60	·59	19	– 1	From Teignmouth Bay.
,,	,,	,,	·93	·55	·95	19	,,	,,
,,	,,	,,	1·30	·69	·73	23	,,	,,
,,	,,	,,	1·18	·77	·70	24	,,	,,
—	—	,,	1·09	·65	·74	21	,,	Average for preceding 4 scales, all from same fish.
14·85 cm. = 5·84 in.	not ascertained	Nov. 2, 1891	1·37	·79	·85	28	– 1	
,,	,,	,,	1·35	·95	·80	27	,,	
,,	,,	,,	1·35	·99	·86	29	,,	
,,	,,	,,	1·32	·98	·76	26	,,	
—	—	—	1·35	·93	·82	28	,,	Average for preceding 4 scales.
15·5 cm. = 6·10 in.	29·25	Sept. 28, 1901	1·28	·83	·70	25	– 1	From Cattewater, Plymouth.
,,	,,	,,	1·32	·90	·72	24	,,	,,
,,	,,	,,	1·22	·80	·72	26	,,	,,
,,	,,	,,	1·36	·90	·67	25	,,	,,
—	—	—	1·30	·86	·70	25	,,	Average for preceding 4 scales, all from same fish.
15·75 cm. = 6·20 in.	28·8	Nov. 4–16, 1901	1·07	·68	·67	23	– 1	From Teignmouth Bay.
,,	,,	,,	1·10	·64	·63	23	,,	,,
,,	,,	,,	·95	·59	·67	20	,,	,,
,,	,,	,,	1·08	·65	·64	22	,,	,,
—	—	—	1·05	·64	·65	22	,,	Average for preceding 4 scales, all from same fish.
15·75 cm. = 6·20 in.	25·62	Nov. 4–16, 1901	1·32	·75	·85	25	– 1	From same locality.
,,	,,	,,	1·28	·80	·85	27	,,	,,
,,	,,	,,	1·05	·65	·70	23	,,	,,
,,	,,	,,	1·20	·80	·70	22	,,	,,
—	—	—	1·21	·75	·78	24	,,	Average for preceding 4 scales, all from same fish.
16·00 cm. = 6·29 in.	29·5	Nov. 4–16, 1901	1·52	1·00	·86	33	– 1	From same locality.
,,	,,	,,	1·29	·85	·75	28	,,	,,
,,	,,	,,	1·48	·97	·80	33	,,	,,
,,	,,	,,	1·48	1·03	·82	31	,,	Average for preceding 4 scales, all from same fish. In the last two specimens the exact length of fish was difficult to determine, on account of broken nature of tail fin.
—	—	—	1·44	·96	·81	31	,,	
16·25 cm. = 6·39 in.	32·9	Nov. 4–16, 1901	1·28	·90	·81	29	– 1	From same locality.
,,	,,	,,	1·30	·81	·70	25	,,	,,
,,	,,	,,	1·23	·80	·74	26	,,	,,
,,	,,	,,	1·35	·88	·82	29	,,	,,
—	—	—	1·29	·85	·77	27	,,	Average for preceding 4 scales, all from same fish.

TABULAR RESULTS OF EXAMINATION OF SCALES OF WHITING—*continued.*

FISH.			SCALES.					
Length.	Weight in grms.	Date of capture.	Length in mm.	Maximum breadth in mm.	Length of A B[1].	No. of lines of growth.	No. of annual rings.	NOTES.
16·5 cm. = 6·49 in.	not ascertained.	Nov. 2, 1891	1·51	1·07	·90	30	−1	
,,	,,	,,	1·40	·94	·95	28	,,	
,,	,,	,,	1·50	1·05	·91	29	,,	
,,	,,	,,	1·55	1·02	1·00	30	,,	
—	—	—	1·49	1·02	·94	29	,,	Average for preceding 4 scales.
17 cm. = 6·69 in.	36·9	Nov. 4–16, 1901	1·35	·95	·66	26	−1	From same locality; a few small disintegrated scales.
,,	,,	,,	1·18	·80	·73	25	,,	
,,	,,	,,	1·20	·95	·70	27	,,	
,,	,,	,,	1·35	·95	·70	30	,,	
—	—	—	1·27	·91	·70	27	,,	Average for preceding 4 scales, all from same fish.
17·25 cm. = 6·79 in.	42·87	Nov. 4–16, 1901	1·50	1·02	·92	32	−1	Fish from same locality; some of the scales showed a break in the continuity somewhat resembling in appearance an annual ring, but these were the exception; also a few very small scales observed.
,,	,,	,,	1·49	·85	·89	30	,,	
,,	,,	,,	1·32	·85	·77	29	,,	
,,	,,	,,	1·46	1·02	·82	31	,,	
—	—	—	1·44	·94	·85	31	,,	Average for preceding 4 scales, all from same fish.
17·75 cm. = 6·98 in.	not ascertained.	Nov. 2, 1891	1·55	1·19	·98	31	−1	
,,	,,	,,	1·72	·92	1·02	33	,,	
,,	,,	,,	1·80	1·26	·97	31	,,	
,,	,,	,,	1·47	1·10	·84	30	,,	
—	—	—	1·64	1·12	·95	31	,,	Average for preceding 4 scales.
17·75 cm. = 6·98 in.	41·6	Nov. 4–16, 1901	1·15	·69	·72	23	−1	From same locality; a few disintegrated scales observed.
,,	,,	,,	1·25	·76	·80	26	,,	
,,	,,	,,	1·26	·78	·80	26	,,	
,,	,,	,,	1·44	1·07	·93	31	,,	
—	—	—	1·28	·83	·81	27	,,	Average for preceding 4 scales, all from same fish.
18·70 cm. = 7·36 in.	51·7	Nov. 4–16, 1901	1·56	1·03	·99	33	−1	From same locality; a few disintegrated and small scales observed.
,,	,,	,,	1·57	1·10	·98	34	,,	
,,	,,	,,	1·36	1·02	·77	29	,,	
,,	,,	,,	1·59	1·10	·90	34	,,	
—	—	—	1·52	1·06	·91	32	,,	Average for preceding 4 scales, all from same fish.
18·75 cm. = 7·38 in.	44·7	Nov. 4–16, 1901	1·34	·75	·88	30	−1	From same locality.
,,	,,	,,	1·22	·80	·79	29	,,	
,,	,,	,,	1·21	·71	·85	27	,,	
,,	,,	,,	1·40	·92	·95	32	,,	
—	—	—	1·29	·80	·87	30	,,	Average for preceding 4 scales, all from same fish.
18·80 cm. = 7·40 in.	56·10	Nov. 4–16, 1901	1·60	1·02	·95	31	−1	From same locality; a very few disintegrated and small scales.
,,	,,	,,	1·53	1·03	·90	30	,,	
,,	,,	,,	1·55	·87	·95	31	,,	
,,	,,	,,	1·74	1·15	1·00	31	,,	
—	—	—	1·61	1·02	·95	31	,,	Average for preceding 4 scales, all from same fish.

TABULAR RESULTS OF EXAMINATION

FISH.			SCALES.				
Length.	Weight in grms.	Date of capture.	Length in mm.	Maximum breadth in mm.	Length of A Bn in mm.	No. of lines of growth in scale.	No. of annual rings.
26·25 cm. = 10·33 in.	134·30	May 14, 1901	2·76	1·98	1·42	47	1+
,,	,,	,,	2·73	1·85	1·37	49	,,
,,	,,	,,	2·93	2·05	1·47	48	,,
,,	,,	,,	2·88	2·07	1·35	42	,,
—	—	—	2·83	1·99	1·40	47	,,
28·5 cm. = 11·22 in.	175	July 16, 1901	3·24	1·46	1·44	40	1+
,,	,,	,,	2·53	1·40	1·27	44	,,
,,	,,	,,	2·37	1·50	1·33	44	,,
,,	,,	,,	2·37	1·52	1·45	44	,,
—	—	—	2·63	1·47	1·37	43	,,
29·5 cm. = 11·61 in.	175	July 16, 1901	2·50	1·45	1·32	41	1+
,,	,,	,,	2·42	1·40	1·19	39	,,
,,	,,	,,	2·08	1·20	1·33	45	,,
,,	,,	,,	2·12	1·25	1·28	40	,,
—	—	—	2·28	1·33	1·28	41	,,
29·65 cm. = 11·67 in.	205	Dec. 2, 1901	2·06	1·70	1·45	54	−2
,,	,,	,,	1·55	1·37	1·24	51	,,
,,	,,	,,	1·96	1·25	1·18	48	,,
,,	,,	,,	2·03	1·32	1·21	46	,,
—	—	—	1·90	1·41	1·27	50	,,
30·15 cm. = 11·87 in.	185	Dec. 2, 1901	2·30	1·65	1·28	42	−2
31·5 cm. = 12·40 in.	215	Dec. 2, 1901	2·49	1·65	1·48	53	−2
,,	,,	,,	2·73	1·70	1·55	51	,,
—	—	—	2·61	1·68	1·52	52	,,

OF SCALES OF WHITING—*continued.*

YEAR I.			YEAR II.		REMARKS.
Total Length in mm.	Length of A B[1] in mm.	No. of lines of growth.	Length of B[1] B[2] in mm.	No. of concentric lines.	
2·00	1·08	37	·34	10	
2·03	1·05	38	·32	11	
2·18	1·12	38	·35	10	
2·14	·95	32	·40	10	
2·09	1·05	36	·35	10	Average for preceding 4 scales.
1·52	·97	27+	·47	13	
1·53	·82	30	·45	14	
1·45	·91	31	·42	13	
1·55	·95	29	·50	15	
1·51	·91	29	·46	14	Average for preceding 4 scales. A number of disintegrated scales.
1·50	·82	27	·50	14	
1·50	·74	25	·45	14	
1·35	·85	31	·48	14	
1·34	·75	25	·48	15	
1·42	·79	27	·48	14	Average for preceding 4 scales, all from same fish.
1·18	·80	30	·65	24	
1·20	·77	30	·47	21	
1·18	·70	29	·48	19	
1·22	·75	26	·46	20	
1·20	·76	29	·52	21	Average.
1·80	·98	32	·30	10	Only scale obtained from this fish (from trawlers).
1·85	1·05	40	·43	13	
1·34	·80	27	·75	24	
1·60	·93	34	·59	19	Only scales obtained from this fish.

TABULAR RESULTS OF EXAMINATION

FISH.			SCALES.				
Length.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of A B^n in mm.	No. of lines of growth.	No. of annual rings.
32·3 cm. = 12·71 in.	257	Oct. 8, 1901	2·13	1·65	1·50	55	– 3
,,	,,	,,	1·73	1·80	1·55	58	,,
,,	,,	,,	2·70	1·95	1·80	69	,,
,,	,,	,,	2·89	2·15	1·82	65	,,
,,	,,	,,	2·74	2·00	1·76	72	,,
,,	,,	,,	3·05	2·20	1·80	70	,,
—	—	—	2·54	1·96	1·71	65	,,
33·2 cm. = 13·07 in.	290	Oct. 8, 1901	2·52	1·59	1·46	57	– 3
,,	,,	,,	2·24	1·87	1·42	61	,,
,,	,,	,,	3·03	1·72	2·07	72	,,
,,	,,	,,	2·40	1·60	1·56	55	,,
,,	,,	,,	2·51	1·90	1·72	59	,,
,,	,,	,,	2·55	1·76	1·51	58	,,
—	—	—	2·54	1·74	1·62	60	,,
33·5 cm. = 13·18 in.	245	Dec. 2, 1901	2·39	1·80	1·62	50	– 2
,,	,,	,,	2·42	1·70	1·62	54	,,
—	—	—	2·91	1·75	1·62	52	,,
34 cm. = 13·38 in.	340	Dec. 12, 1901	2·60	1·90	1·80	63	– 3
,,	,,	,,	2·38	1·85	1·70	59	,,
,,	,,	,,	2·65	1·72	1·58	60	,,
,,	,,	,,	2·08	1·45	1·41	57	,,
—	—	—	2·43	1·73	1·62	60	,,
34·2 cm. = 13·46 in.	290	Oct. 8, 1901	2·48	1·60	1·51	56	– 3
,,	,,	,,	2·80	2·50	1·55	58	,,
,,	,,	,,	2·92	2·22	1·78	61	,,
,,	,,	,,	2·24	2·00	1·31	49	,,
,,	,,	,,	2·76	2·01	1·53	60	,,
,,	,,	,,	2·36	1·90	1·38	54	,,
—	—	—	2·59	2·04	1·51	56	,,
34·5 cm. = 13·58 in.	335	Jan. 10, 1902	2·39	2·10	2·40	72	– 3
34·92 cm. 13·75 in. =	255	Dec. 2, 1901	2·96	2·15	1·79	70	– 3

OF SCALES OF WHITING—*continued.*

YEAR I.			YEAR II.		YEAR III.		REMARKS.
Total length in mm.	Length of A B^1 in mm.	No. of lines of growth.	Length of $B^1 B^2$ in mm.	No. of lines of growth.	Length of $B^2 B^3$ in mm.	No. of lines of growth.	
1·20	·87	31	·20	10	·43	14	A few scales showed disintegration; apparently a very small growth in 2nd year, especially winter growth.
1·50	1·00	34	·15	10	·40	14	
1·55	1·00	37	·25	12	·55	20	
1·70	·98	37	·25	10	·59	18	
1·68	1·10	44	·21	10	·45	18	
1·78	1·00	41	·25	10	·55	19	
1·57	·99	37	·22	10	·50	17	Average for preceding 6 scales, all from [same fish.
1·70	·90	35	·22	10	·34	12	
1·65	1·07	43	·14	8	·21	10	
2·00	1·36	46	·33	12	·38	14	
1·63	1·00	33	·23	10	·33	12	
1·58	1·07	36	·26	10	·39	13	
1·53	·85	33	·31	13	·35	12	
1·68	1·04	38	·25	10–11	·33	12	Average for preceding ½-dozen scales, all from same fish, Jan. 7, 1902.
1·60	1·05	34	·57	16	—	—	
1·55	1·00	34	·62	20	—	—	Many scales on this fish were in a dis- [integrated condition.
1·58	1·03	34	·60	18	—	—	Average.
1·70	1·15	40	·40	13	·25	10	
1·30	·95	33	·45	17	·30	9	
1·50	·95	34	·42	16	·21	10	
1·27	·82	32	·42	17	·17	8	
1·44	·97	35	·42	16	·23	9	Average.
·75	·43	16	·55	20	·53	20	
·85	·45	18	·60	19	·50	21	Many disintegrated scales.
·90	·50	18	·73	23	·55	20	N.B.—Small growth of first year.
·65	·35	12	·46	18	·50	19	
·85	·44	18	·57	21	·52	21	
·66	·38	14	·50	18	·50	22	
·78	·43	16	·57	20	·52	20–21	Average.
1·80	1·10	32	·65	20	·65	20	Few scales on this fish, as it came from the trawlers.
1·55	·94	38	·45	18	·40	14	

TABULAR RESULTS OF EXAMINATION

FISH.			SCALES.					YEAR I.		
Length in cm.	Weight in grms.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of AB^n in mm.	No. of lines of growth.	No. of annual rings.	Total length in mm.	Length of AB^1 in mm.	No. of lines of growth.
34·92 = 13·75 in.	320	Dec. 2, 1901	2·76	1·95	1·68	59	– 4 ?	·50	·28	8*
,,	,,	,,	2·52	1·85	1·76	63	– 4	·45	·26	7
—	—	—	2·64	1·90	1·72	61	,,	·48	·27	8
35·56 = 14 in.	395	Dec. 2, 1901	2·55	1·95	1·51	58	– 3	1·35	·76	30
,,	,,	,,	2·56	2·00	1·57	59	,,	1·30	·75	30
—	—	—	2·56	1·98	1·54	59	,,	1·33	·76	30
35·56 = 14 in.	280	Dec. 2, 1901	2·40	1·68	1·42	53	– 3	1·25	.65	20
,,	,,	,,	2·61	2·00	1·57	61	,,	1·75	·96	30
—	—	—	2·51	1·84	1·50	57	,,	1·50	·81	25
36·195 = 14·25 in.	355	Dec. 2, 1901	2·38	2·10	1·47	60	– 3	1·50	·87	36
,,	,,	,,	2·32	1·85	1·52	61	,,	1·45	·92	34
—	—	—	2·35	1·98	1·50	61	,,	1·48	·90	35
36·195 = 14·25 in.	355	Dec. 2, 1901	1·80	1·30	1·42	43	– 3	1·10	·95	24
36·83 = 14·50 in.	332	Dec. 2, 1901	2·76	1·80	1·58	49	– 3	1·55	·83	26
40 005 = 15·75 in.	455	Dec. 2, 1901	2·86	1·90	1·86	72	– 3	1·30	·80	31
,,	,,	,,	3·10	2·00	2·01	71	,,	1·40	·85	31
,,	,,	,,	2·55	1·98	1·68	68	,,	1·25	·78	31
,,	,,	,,	2·66	2·37	1·74	66	,,	1·30	·84	32
—	—	—	2·79	2·06	1·82	69	,,	1·31	·82	31
41·275 = 16·25 in.	500	Dec. 2, 1901	3·44	2·30	2·14	74	– 3	1·66	·92	34
,,	,,	,,	3·10	2·40	2·51	75	,,	1·50	·98	31
,,	,,	,,	3·55	2·36	2·35	75	,,	1·50	·90	30
,,	,,	,,	3·29	1·67	2·27	72	,,	1·26	·97	29
—	—	—	3·35	2·18	2·32	74	,,	1·48	·94	31
46·6 = 18·34 in.	700	Jan. 10, 1902	3·28	2·15	1·65	70	– 4	·70	·40	21
,,	,,	,,	3·07	1·75	1·65	71	,,	·65	·40	20
,,	,,	,,	3·47	2·15	2·00	81	,,	·85	·48	20
,,	,,	,,	3·80	2·10	1·67	71	,,	1·00	·47	26
—	—	—	3·41	2·04	1·74	73	,,	·80	·44	22
49 = 19·29 in.	763·42	May 14, 1901	3·54	2·90	2·15	78	4 +	1·55	·85	27
,,	,,	,,	3·54	2·40	1·94	65	,,	1·53	·93	30
,,	,,	,,	3·52	2·45	2·20	75	,,	1·50	·90	30
,,	,,	,,	3·98	3·10	2·37	76	,,	1·70	·95	29
—	—	—	3·65	2·71	2·17	74	,,	1·57	·91	29

* Some concentration of lines at this point.

OF SCALES OF WHITING—*continued.*

YEAR II.		YEAR III.		YEAR IV.		YEAR V.		REMARKS.
Length of B^1B^2 in mm.	No. of lines of growth.	Length of B^2B^3 in mm.	No. of lines of growth.	Length of B^3B^4 in mm.	No. of lines of growth.	Length of B^4B^5 in mm.	No. of ex-centric lines.	
·59	24	·35	11	·46	16	—	—	Remarkably small scale growth for first year; also marked disintegration of
·63	25	·40	17	·47	14	—	—	large number of scales. Yrs. I. and II. should perhaps be Year I.
·61	25	·38	14	·47	15	—	—	Average.
·40	16	·35	12	—	—	—	—	
·42	14	·40	15	—	—	—	—	
·41	15	·38	14	—	—	—	—	Average.
·40	17	·37	16	—	—	—	—	
·36	20	·25	11	—	—	—	—	
·38	19	·31	14	—	—	—	—	Average.
·35	14	·25	10	—	—	—	—	
·25	13	·35	14	—	—	—	—	
·30	14	·30	12	—	—	—	—	Average.
·28	13	·19	6	—	—	—	—	
·50	14	·25	9	—	—	—	—	
·63	24	·43	17	—	—	—	—	
·66	24	·48	16	—	—	—	—	
·50	25	·40	13	—	—	—	—	
·55	22	·35	12	—	—	—	—	
·59	24	·42	15	—	—	—	—	Average.
·74	18	·48	22	—	—	—	—	
·95	23	·58	21	—	—	—	—	Many of the scales from the last
·80	25	·65	20	—	—	—	—	fish were in a disintegrated con-
·80	24	·50	19	—	—	—	—	dition.
·82	23	·55	21	—	—	—	—	Average.
·55	22	·35	13	·35	14	—	—	This is a corrected observation:
·65	25	·35	14	·25	12	—	—	in my previous observation I had
·80	30	·40	16	·32	15	—	—	evidently put Years III. and IV.
·60	23	·30	11	·30	11	—	—	together as one year.
·65	25	·35	14	·31	13	—	—	Average.
·50	19	·40	14	·30	14	·10	4	
·40	13	·29	12	·20	7	·12	3	
·47	16	·35	12	·35	14	·13	3	
·57	18	·38	13	·35	13	·12	3	
·49	17	·38	13	·30	12	·12	3	Average.

EXAMINATION OF SCALES OF WHITING—*Summary.*

Length of fish.		Weight in grms.	Month of capture.	Annual rings.	Lines of growth.					Locality.	Approximate age.
cm.	inches.				I.	II.	III.	IV.	V.		
5·4	2·12	1·12	June	−1	3	–	–	–	–	From English Channel	3–4 months.
7·8	3·07	2·85	Oct.	,,	11	–	–	–	–	From North Sea	
8·2	3·22	3·47	,,	,,	9	–	–	–	–	,,	
8·4	3·30	3·44	,,	,,	10	–	–	–	–	,,	
9·8	3·85	3·97	,,	,,	10	–	–	–	–	,,	
11·0	4·33	9·0	Nov.	,,	19	–	–	–	–	From English Channel	8 months.
11·5	4·52	9·09	,,	,,	15	–	–	–	–	,,	,,
11·90	4·68	10·15	,,	,,	16	–	–	–	–	,,	,,
12·20	4·80	12·8	,,	,,	21	–	–	–	–	,,	,,
12·40	4·88	15·40	,,	,,	20	–	–	–	–	,,	,,
13·0	5·11	fish damaged	Sept.	,,	19	–	–	–	–	,,	6–7 months.
13·65	5·37	17·4	Nov.	,,	20	–	–	–	–	,,	8 months.
14·0	5·51	18·75	,,	,,	24	–	–	–	–	,,	,,
14·65	5·76	23·15	Sept.	,,	24	–	–	–	–	,,	6–7 months.
14·75	5·80	26·90	Nov.	,,	21	–	–	–	–	,,	8 months.
14·85	5·84	not taken	,,	,,	28	–	–	–	–	,,	,,
15·5	6·10	29·25	Sept.	,,	25	–	–	–	–	,,	6–7 months.
15·75	6·20	28·8	Nov.	,,	22	–	–	–	–	,,	8 months.
15·75	6·20	25·62	,,	,,	24	–	–	–	–	,,	,,
16·0	6·29	29·5	,,	,,	31	–	–	–	–	,,	,,
16·25	6·39	32·9	,,	,,	27	–	–	–	–	,,	,,
16·50	6·49	not taken	,,	,,	29	–	–	–	–	,,	,,
17·0	6·69	36·9	,,	,,	27	–	–	–	–	,,	,,
17·25	6·79	42·87	,,	,,	31	–	–	–	–	,,	,,
17·75	6·98	not taken	,,	,,	31	–	–	–	–	,,	,,
17·75	6·98	41·6	,,	,,	27	–	–	–	–	,,	,,
18·70	7·36	51·7	,,	,,	32	–	–	–	–	,,	,,
18·75	7·38	44·7	,,	,,	30	–	–	–	–	,,	,,
18·80	7·40	56·10	,,	,,	31	–	–	–	–	,,	,,
26·25	10·33	134·30	May	1+	36	10	–	–	–	,,	1 yr. 2–3 mths.
*28·50	11·22	175	July	,,	29	14	–	–	–	,,	1 yr. 4–5 mths.
29·50	11·61	175	,,	,,	27	14	–	–	–	,,	,,
29·65	11·67	205	Dec.	−2	29	21	–	–	–	,,	1 yr. 9 mths.
30·15	11·87	185	,,	,,	32	10	–	–	–	,,	,,
31·50	12·40	215	,,	,,	34	19	–	–	–	,,	,,
32·30	12·71	257	Oct.	−3	37	10	17	–	–	,,	2 yrs. 7 mths.
33·2	13·07	290	,,	,,	38	10–11	12	–	–	,,	,,
33·5	13·18	245	Dec.	−2	34	18	–	–	–	,,	1 yr. 9 mths.
†34·0	13·38	340	Jan.	−4	31	21	10	9	–	,,	3 yrs. 10 mths.
34·2	13·46	290	Oct.	−3	16	20	20 or 21	–	–	,,	2 yrs. 7 mths.
34·5	13·58	335	Jan.	,,	32	20	20	–	–	,,	2 yrs. 10 mths.
34·92	13·75	255	Dec.	−3?	33	14	15	–	–	,,	
34·92	13·75	320	,,	−3	38	18	14	–	–	,,	2 yrs. 9 mths.
35·56	14·0	395	,,	,,	30	15	14	–	–	,,	,,
35·56	14·0	280	,,	,,	25	19	14	–	–	,,	,,
36·19	14·25	355	,,	,,	35	14	12	–	–	,,	,,
36·19	14·25	355	,,	,,	24	13	6	–	–	,,	,,
36·83	14·50	332	,,	,,	26	14	9	–	–	,,	,,
40·0	15·75	455	,,	,,	31	24	15	–	–	,,	,,
41·27	16·25	500	,,	,,	31	23	21	–	–	,,	,,
46·6	18·34	700	Jan.	−4	22	25	14	13	–	,,	3 yrs. 10 mths.
‡49·0	19·29	763·42	May	4+	29	17	13	12	3	,,	4 yrs. 2 mths.

* See Pl. VI., Fig. 1. † See Pl. VI., Fig. 2. ‡ See Pl. VII., Fig. 1.

GADUS MERLANGUS.

Summarised Table of Annual Rings.

No. of fish.	Length of fish. in cm.	Length of fish. in inches.	Month of capture.	No. of annual rings.	No. of lines of growth (excentric lines) in years. 1	2	3	4	5	Remarks.
1	5·4	2·12	June	–1	3	–	–	–	–	From North Sea.
1	7·8	3·07	October	,,	11	–	–	–	–	
2	8·0	*s. 3·22 L. 3·30	,,	,,	9–10	–	–	–	–	
1	9·8	3·85	,,	,,	10	–	–	–	–	
4	11–12	s. 4·33 L. 4·80	November	,,	15–21	–	–	–	–	
3	12–13	s. 4·88 L. 5·37	,,	,,	19–20	–	–	–	–	
5	14·	s. 5·51 L. 5·84	Oct. to middle November	,,	21–28	–	–	–	–	
6	15–16	s. 6·10 L. 6·49	,,	,,	22–31	–	–	–	–	
4	17·0	s. 6·69 L. 6·98	November	,,	27–31	–	–	–	–	
3	18·0	s. 7.36 L. 7·40	,,	,,	30–32	–	–	–	–	
1	26·25	10·33	May	1+	36	10	–	–	–	
3	28–29	s. 11·22 L. 11·67	July to Dec.	1+to–2	27–29	14–21	–	–	–	
2	30–31	s. 11·87 L. 12·40	Dec.	–2	32–34	10–19	–	–	–	
1	32·3	12·7	October	–3	37	10	17	–	–	
1	33·2	13·07	,,	,,	38	10	12	–	–	
1	33·5	13·18	December	–2	34	18	–	–	–	
4	33–34	s. 13·3 L. 13·97	Oct. to Jan.	–3	16–38	16–20	9–21	–	–	
1	34·92	13·75	December	–3?	34	14	15	–	–	
5	35–36	s. 14·0 L. 14·50	,,	–3	24–35	13–19	6–14	–	–	
2	40–41	s. 15·75 L. 16·25	,,	,,	31	23–24	15–21	–	–	
1	46·6	18·34	January	,,	23	31	24	–	–	
1	46·6	18·34	,,	–4	22	25	14	13	–	
1	49·0	19·29	May	4+	29	17	13	12	3	

* Have here taken the smallest (s.) and largest (L.) fish.

SUMMARISED TABLE SHOWING AVERAGE SURFACE SIZE OF SCALES IN WHITING AT VARIOUS STAGES.

No. of fish.	Range of length in cm.	Range of weight in grms.	Month of capture.	Average length of scale in mm.	Average length of AB^1 or AB^1 in mm.	Average breadth of scale in mm.	Average lines of growth (excentric lines) in years I.	II.	III.	IV.	V.	Notes.
1	5·4	1·12	June	·33	·19	·28	3	–	–	–	–	
4	7·8–9·8	2·85–3·97	Oct.	·60	·35	·42	10	–	–	–	–	From North S
25	11·0–18·80	9·0–56·10	Oct. to Nov.	1·16	·70	·77	24	–	–	–	–	
					AB^n							
1	26 25	134·30	May	2·83	1·40	1·99	36	10	–	–	–	
2	28·5–29 5	175	July	2·45	1·32	1·40	28	14	–	–	–	
3	29·65–31·5	205–215	Dec.	2·27	1·35	1·58	32	13	–	–	–	
2	32·3–33·2	257–290	Oct.	2·54	1·66	1·85	38	10	15	–	–	
7	35·56–41·27	280–500	Dec.	2·59	1·67	1·88	29	17	13	–	–	
1	46·6	700	Jan.	3·41	1·74	2·04	22	25	14	13	–	
1	49·0	763·42	May	3·65	2·17	2·71	29	17	13	12	3	

GADUS MERLANGUS (WHITING).

Length of fish in cm.	Age of fish.
5·4	First summer.
7–18	,, winter.
26–29	Second summer.
29–31	,, winter.
32–42	Third ,,
(33·5	Second ,,)
(34·0	Fourth ,,)
46·6	,, ,,
49·0	Fifth spring.

For purposes of comparison I submit two tables of ages for the Whiting, the first table from Fulton's paper on "The Rate of Growth of the Cod, Haddock, Whiting, and Norway Pout" (*Fishery Board for Scotland*, 1900); the second table from Cunningham's paper on "The Rate of Growth of some Sea Fishes and their Distribution at Different Ages" (*Journal Marine Biological Association*, vol. ii., n.s., 1891–2).

Table showing the Rate of Growth of the Whiting (*Gadus merlangus*), after Fulton.

		Size.		Approximate age.		Apparent growth in a year from previous series.	
		mm.	inches.	yrs.	mths.	mm.	inches.
A Series (6,203 fish).	Smallest	69	$2\frac{11}{16}$	–	2	–	–
	Average	124·4	$4\frac{7}{8}$	–	$5\frac{1}{2}$	–	–
	Largest	196	$7\frac{11}{16}$	–	7	126	$4\frac{11}{16}$
B Series (1,168 fish).	Smallest	183	$7\frac{1}{4}$	1	2	114·0	$4\frac{1}{2}$
	Average	237·9	$9\frac{3}{8}$	1	$5\frac{1}{2}$	113·5	$4\frac{1}{2}$
	Largest	297	$11\frac{11}{16}$	1	7	101	4
*C Series (1,110 fish).	Smallest	257	$10\frac{1}{8}$	2	2	74	$2\frac{15}{16}$
	Average	313·5	$12\frac{5}{16}$	2	$5\frac{1}{2}$	75·6	3
	Largest	404	$15\frac{7}{8}$	2	7	107	$4\frac{3}{16}$
*D Series (30 fish).	Smallest	410	$16\frac{1}{8}$	3	2	[153	6
	Average	469·4	$18\frac{1}{2}$	3	$5\frac{1}{2}$	[155·9	$6\frac{1}{8}$]
	Largest	491	$19\frac{5}{16}$	3	7	[87	$3\frac{3}{8}$]
*E Series (5 fish).	Smallest	526	$20\frac{11}{16}$	[4	2]	[116	$4\frac{9}{16}$]
	Average	534·2	21	[4	$5\frac{1}{2}$]	[64·8	$2\frac{9}{16}$]
	Largest	541	$21\frac{5}{16}$	[4	7]	[50	

* Deep water hauls.

Table showing the Rate of Growth of the Whiting (*Gadus merlangus*), after Cunningham.

Date of collection.	No. of specimens	Length in cm.	Length in in.	Calculated age.
June 13, 1889	2	5·7	2·2	3 or 4 months old.
July 16, 1891	13	5·4–9·0	2·1–3·5	4 or 5 months old.

I must notice here the case of a whiting which I kept living under observation in one of the small tanks of the laboratory, from a month or so after hatching until it was one year and four or five months old. When first placed in the tank, in early May, 1902, this whiting measured 10–20 mm. in length (according to Cunningham the larval whiting when first hatched is 3·6 mm. in length). The whiting in question was fed regularly from the hand until July 4th, 1903, when it leapt from the tank. At the latter date it measured $8\frac{1}{2}$ inches in length, and was $3\frac{1}{8}$ oz. in weight. On examining its scales I found them much more regular in their arrangement than the scales of whiting captured at sea. The lines of growth appeared almost uniformly separated from one another, and because of this I could not observe any distinction into summer and winter areas such as are marked out in my plates.

Another noteworthy point about the lines of growth in the scales of this whiting was that they appeared throughout to be closer to one another than is the case in captured fish. This would probably indicate a uniformly slower growth of the scale.

The temperature of the water in the Plymouth tanks remains fairly constant; but there is naturally a distinct difference between the summer and winter temperature, and the whiting in question may be taken as having been fairly regularly supplied with food. From these facts, and also from the fact that fish from deep water, where the temperature of the sea does not show marked variation in summer and winter, show annual rings as clearly as those from shallow water where there is a marked difference between the summer and winter temperature, inclines me to believe that it is a question of variation in the food-supply rather than variation in temperature which influences the metabolism of the fish, and indirectly brings about the formation of annual rings in scales.

The scales of this aquarium whiting showed, however, some interesting points, firstly as to the number of lines of growth: the total number of these lines was on an average 50, and whiting from the sea which I determined to be of about the same age, though of a larger size (see tables), showed on an average 43 lines of growth. It appears to me, if I had not already known the real age of this captive whiting, that from my tables of calculated ages for captured whiting I would at least have arrived at the approximate age by counting the number of lines of growth in the scales.

In regard to the sizes of scales in this captive whiting, they were on an average the following: Total length of scale, 2·00 mm.; maximum breadth of scale, 1·50 mm.; long axis AB^n, 1·10 mm. On comparing the figures above with those given in my tables, it seems that the size of the scale is small for the number of growth lines present, and this one might expect from my previous observation that the growth lines are all uniformly closely adjacent to one another.

The Haddock *(Gadus aeglefinus)*.

Tabular Results of Examination of Scales of Haddock.

FISH.			SCALES.					YEAR I.			YEAR II.		YEAR III.		REMARKS.
Length in cm.	Weight.	Date of capture.	Total length in mm.	Maximum breadth in mm.	Length of AB^n in mm.	No. of excentric lines in AB^n	No. of annual rings.	Total length of year's growth in mm.	Length of AB^1 in mm.	No. of excentric lines.	Length of B^1B^2 in mm.	No. of excentric lines.	Length of B^2B^3 in mm.	No. of excentric lines.	
26·25 = 10·33 in.	6½ oz.	May 15, 1901	2·83	1·50	1·65	38	2	1·44	·83	20	·82	18	—	—	
,,	,,	,,	2·72	1·38	1·85	42	2	1·55	·89	21	·96	21	—	—	
,,	,,	,,	2·71	1·76	1·56	39	2	1·45	·80	20	·76	19	—	—	
,,	,,	,,	3·04	1·65	1·62	41	2	1·64	·82	21	·80	20	—	—	
—	—	—	2·83	1·57	1·67	40	2	1·52	·84	21	·84	20	—	—	Average for preceding 4 scales, all from same fish.
29 = 11·41 in.	9¼ oz.	May 15, 1901	2·81	1·67	1·63	39	2+	1·43	·87	19	·68	16	·08	4	
,,	,,	,,	2·84	1·70	1·65	38	2+	1·37	·77	17	·78	17	·10	4	
,,	,,	,,	2·79	1·56	1·55	40	2+	1·29	·70	19	·78	20	·07	1	
,,	,,	,,	2·67	1·43	1·49	42	2+	1·25	·65	18	·74	20	·10	4	
—	—	—	2·78	1·59	1·58	40	2+	1·34	·75	18	·75	18	·09	3	Average for preceding scales, all from same fish.
35 = 13·77 in.	14¼ oz.	May 15, 1901	3·13	1·55	1·71	47	2+	1·70	·90	24	·74	19	·07	4	
,,	,,	,,	2·93	1·90	1·63	43	2+	1·68	·93	23	·60	16	·10	4	
,,	,,	,,	3·30	1·80	1·83	45	2+	1·80	1·00	24	·67	16	·16	5	
,,	,,	,,	2·93	1·82	1·75	42	2+	1·58	·90	22	·63	15	·22	5	
—	—	—	3·07	1·77	1·73	44	2+	1·69	·93	23	·66	17	·14	5	Average for preceding scales, all from same fish.

HADDOCK, *from the North Sea.*

Length of fish. in.	Length of fish. cm.	Weight.	No. of annual rings in scale.	Date of capture.	Approximate age.	Notes.
10½	26·67	6½ oz.	2	May 15, 1901	2 years.	No clearly marked growth for spring of 1901.
11⅝	29·52	9¼ oz.	2+	,,	2 years 1 month	Clearly marked growth for spring of 1901.
12¾	32·38	12 oz.	,,	,,	,,	Ditto.
13⅛	33·33	12 oz.	,,	,,	2 yrs. 1–2 mths.	1st year's growth small; 2nd year normal; much growth for spring of 1901.
13⅛	33·33	12¼ oz.	,,	,,	2 years 1 month	Spring growth of 1901 apparent.
14	35·56	14¼ oz.	,,	,,	,,	,, ,,
14¼	36·19	15¾ oz.	,,	,,	,,	,, ,,
15½	39·37	1 lb. 5¾ oz.	3	,,	3 years	Very little, if any growth for spring of 1901.
16¼	41·27	1 lb. 12¼ oz.	3+	,,	3 years 1 month	Spring growth of 1901 more clearly marked than in last.
20¼	51·43	2 lbs. 9½ oz.	4+	,,	4 years 1 month	Spring growth of 1901 apparent.
21½	54·61	4 lbs.	,,	,,	,,	,, ,,

N.B.—These haddocks were probably hatched in May. According to Fulton the majority of larval haddocks are probably hatched in early April, and it may be later, as spawning fish can be obtained as far on as the beginning of May.

AGE OF HADDOCK AS DETERMINED BY FULTON.

Length.		Age.
Series A. Range from 4⅝ to 8¾ in.	Average length, 6 5/16 inches	7 to 8 months in October.
Series B. Range up to 13¾ inches	Average length, 11½ inches	1 year 7 months ,,
Series C. Range up to 17¼ inches	Average length, 13½ to 14 in.	2 years 7 months ,,

The Cod *(Gadus callarias, L.)*.

Length of fish.	Date of capture.	No. of annual rings in scale.	No. of lines of growth.		Approximate age.
			Year 1.	Year 2.	
9·87 in. = 25·08 cm.	August 26, 1902	1 +	19	9	1 year 4–5 months.
,,	,,	,,	19	10	,,
,,	,,	,,	20	9	,,
,,	,,	,,	17	10	,,
,,	,,	,,	20	10	,,
,,	,,	,,	20	10	,,
—	—	—	19	10	Average of scales, all from [same fish.
8·25 in. = 20·95 cm.	August 26, 1902	1 +	15	8	1 year 4–5 months.
,,	,,	,,	13	8	,,
,,	,,	,,	14	8	,,
,,	,,	,,	12	9	,,
,,	,,	,,	15	8	,,
,,	,,	,,	13	8	,,
—	—	—	14	8	Average of scales, all from [same fish.

NOTE.—The ages thus determined agree with Fulton's results. According to Fulton, the majority of Cod probably hatch about the end of March and early part of April, and this may be taken as the period from which to date the average age of the season's brood, and Haddock $8\frac{1}{4}$ to $11\frac{1}{4}$ inches long are 1 year and 5 months in September.

The Scales of Eels.

This paper commenced with the scales of the eel, and towards my conclusion I must again refer to them.

I have recently obtained eels from the Isle of May, Firth of Forth, in order to examine their scales to see if by this means I could throw any light on their interesting life-history. I endeavoured to obtain eels from the lighthouse-keeper of the isle during the past winter (1902–1903), but was informed by him that they were never seen there during winter. He thought they must bury themselves in the mud at the bottom of the loch during winter-time, and it seems probable that at this season they indulge in a winter sleep. In the following August, however, the lighthouse-keeper was kind enough to send me three eels, measuring 28, 33, and 35 inches respectively. The eels of the Isle of May have previously attracted the attention of the biologist on account of their supposed history. They were supposed to have been introduced there by the monks some centuries ago, and to have lived in the land-locked loch on the isle since that time. It had been held for sometime that eels could only breed in salt water, and that those eels prevented from reaching salt water by their land-locked habitat were the identical eels brought over by the monks, being therefore of great age. Sandeman has contributed a paper to the Linnean Society showing that the eyes and other organs show symptoms of senile decay.

Lately, in the *Field,* it has been held that eels can breed in fresh water. The lighthouse-keeper on the isle tells me that the eels found by him are much smaller than those found formerly, that instead of being five feet or so, they are only three feet or so in length.

The scales of eels are well buried in the skin, and from this position one would naturally suppose that they could not easily be shed or rubbed off. The scales show rings very clearly; but whether these are annual or not I would not at present certainly determine, as I have not a complete series of the fish. If the rings are annual, and from the fact that these animals seem to have a winter sleep, it would be natural to suppose that such is the case, then the eels on the Isle of May are of no great age, and the largest of the specimens (35 inches in length) examined by me, may not be more than fourteen years old, but on this determination I do not place any exact reliance.

The scales were thick, well preserved, and showed no signs of disintegration such as are found in scales from aged pollack. This may be partly accounted for by the fact that scales in the eel do not overlap one another.

IV. Conclusion.

My present paper, firstly, rests on the foundation of Dr. Hoffbauer's work for fresh-water fish, which no authority has as yet proved false. Dr. Hoffbauer showed that scales gave a direct index of age in carp, etc., for all of which he had exact and direct knowledge as to their age and history. It is surely opposed to the principle of the unity of science to believe that a law which holds true for some fresh-water fish would not also be found applicable to some marine fish.

After reading the preceding statistics, I think that it must be granted that, even after allowing for variation, they afford strong cumulative proof that in these species of Gadidæ the growth of scales is cyclical or periodic, and that the rings formed thereby are annual. To believe that these are not annual rings, but are rings formed in some more irregular manner, seems quite opposed to the facts in regard to the growth of the scale, and the arrangement of the lines which mark that growth, as brought out by my statistics and plates.

That scales of those Gadidæ show a larger surface growth, and a wider separation of the lines of growth in summer as contrasted with winter, appears to me to be indisputable. This divergence in the growth of scales during summer and winter is probably due to changes in the general metabolism of the body, which are in their turn, in all probability, the result of seasonal variation in the temperature and food-supply. Of these two causes I am more inclined to give preponderance to the latter.

After an examination of thousands of scales from these Gadidæ I hold that in ninety-eight cases out of a hundred one would arrive at a very closely approximate idea of the age of the fish from an examination of three or four well-developed scales taken from the median region of the flanks near the lateral line. Other areas of the body show annual rings in the scales, but in the area mentioned they are more easily determined than elsewhere. The percentage given would be less in the case of fish more than four or five years of age, for reasons already stated in a previous part of this paper. In this connection, however, it has to be remembered that the determination of age for younger is of more practical importance than for older fish.

Corroboration of the truth of this hypothesis, that the ages of certain marine fishes may be determined by means of annual rings on the scales is afforded by the fact that the ages ascertained by my method agree in the main with the results calculated out by other workers who have worked at the subject of the age of fish from a different standpoint. In this connection I have quoted repeatedly from Cunningham and Fulton, the latter of whom has worked out the subject in a very complete manner after Petersen's method (*Scottish Fishery Board*, 1900 and 1901).

Allowing for difference of locality of capture, my results agree in the main with those of Fulton, and they also afford many points of agreement with Cunningham's results for fish of the English Channel. As I have already stated, I had little previous knowledge of Mr. Cunningham's and Dr. Fulton's results on the probable ages of fish, and it was only after I compiled my own statistics on age-determination that I compared them with those of other workers.

It is almost impossible to acquire direct proof of this hypothesis, the conditions of life in tank and aquarium being so unlike the natural haunts, yet even with this, I have already mentioned that in the case of a whiting which lived from shortly after hatching for thirteen and a quarter months in a tank, the number of growth-lines formed on the scale during that period roughly agreed (after allowing for a slower scale growth under captive conditions) with the number of growth-lines in the scales from sea whiting calculated to be about the same age.

The labelling of Gadidæ as adopted for other fish by the International Sea Fisheries Scheme along with an examination of their scales would, I believe, furnish a direct proof of this hypothesis.

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EXPLANATION OF PLATES.

Plates I. to IV., Photo-micrographs of Scales of Pollack.
Plate V., Scales of Poor Cod.
Plate VI., Scales of Whiting.
Plate VII., Fig. 1, Scale of Whiting; Fig. 2, Scale of Coal Fish (*Gadus virens*).
Plate VIII., Fig. 1, Scale of Haddock; Fig. 2, Scale of Norwegian Whiting Pollack (*Gadus Esmarkii*).

The lettering is taken in each case from the posterior area of the scale.

C = Centre of growth.
C – W 1 = Growth of first year.
C – S 1 = Growth of first summer.
S 1 – W 1 = Growth of first winter.
W 1 – S 2 = Growth of second summer.
W 1 – W 2 = Growth of second year.
W 2 – W 3 = Growth of third year.
L.G. = Lines of growth.
S.L.G. = Summer lines of growth.
W.L.G. = Winter lines of growth.

PLATE I.

Fig. 1.—Scale of young Pollack, 3 to 4 months old, magnified about 140 diameters. Length of fish, 5·4 cm. (2·12 in.); date of capture, July, 1901. Scale shows three lines of growth. The figure was drawn with the aid of the camera.

Fig. 2.—Scale of Pollack, 7 to 8 months old, magnified about 45 diameters. Length of fish, 10·15 cm. (3·99 in.); date of capture, December 4th, 1889; number of lines of growth, 18. The later lines are closer to one another than the earlier, indicating winter growth as distinguished from summer growth. The distance between two consecutive summer lines of growth is seen, from the Figures 2, 3, and 4, to be in some cases half as much again as the distance between two consecutive lines of winter growth; in other cases it may be twice as great.

Fig. 3.—Scale of pollack, 7 to 8 months old, magnified 45 diameters. Length of fish, 10·0 cm. (3·93 in.); date of capture, December, 1889. Shows 20 lines of growth.

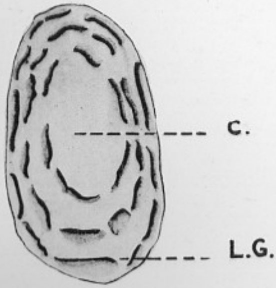
Fig. 4.—Scale of Pollack, 7 to 8 months old, magnified 45 diameters. Length of fish, 11·75 cm. (4·62 in.); date of capture, December 4th, 1889; number of lines of growth, 20. The later lines are closer to one another than the earlier lines, indicating winter growth as distinguished from summer growth.

Fig. 5.—Scale of Pollack, 1 year 2 to 3 months old, magnified 37½ diameters. Length of fish, 24·76 cm. (9·75 in.); date of capture, May, 1902; number of lines of growth first year, 26, 8 lines the early growth of the second year.

PLATE II.

Fig. 1.—Pollack scale at end of second summer, magnified 45 diameters. Length of fish, 28·5 cm. (11·22 in.); date of capture, October, 1900; age determined, 1 year 6 to 7 months.

Fig. 2.—Pollack scale at end of second year. Length of fish, 33·65 cm. (13·25 in.); date of capture, May, 1902. This photo-micrograph has, owing to the larger size of the scale, been magnified much less than preceding scale.



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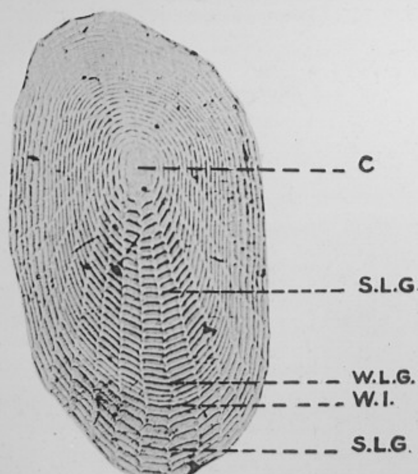

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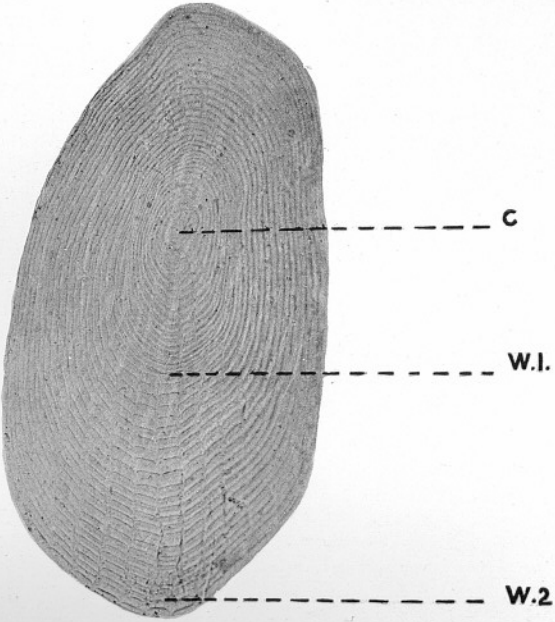

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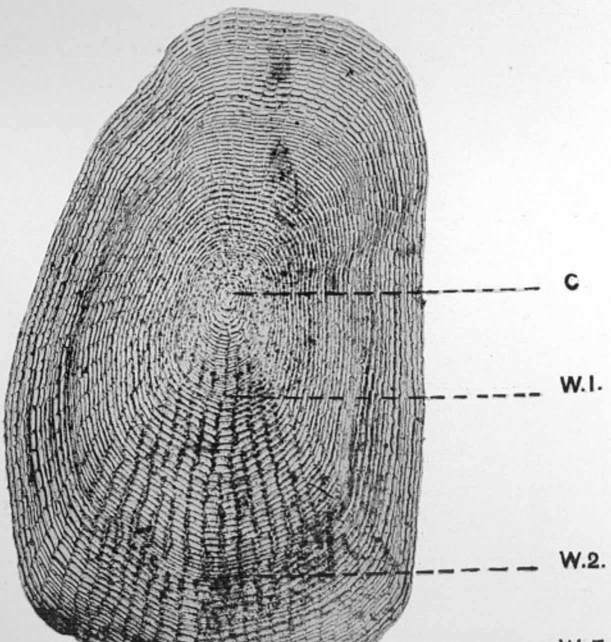

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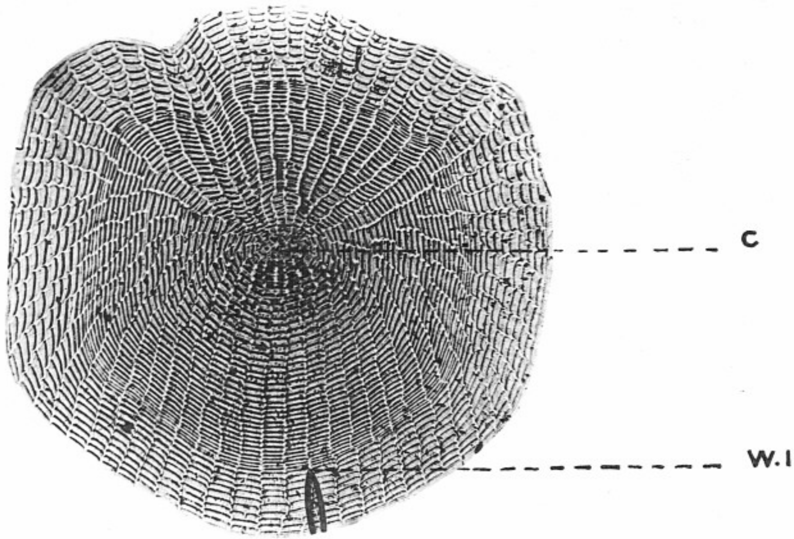

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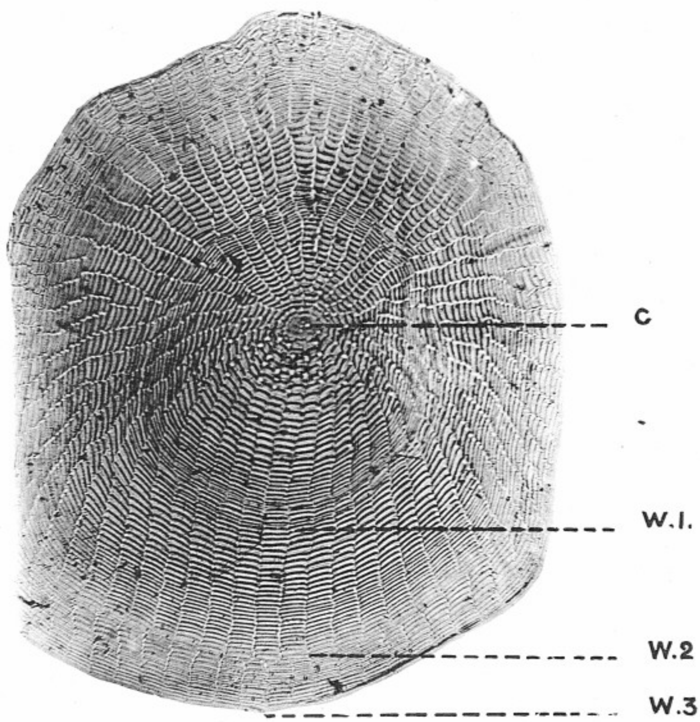

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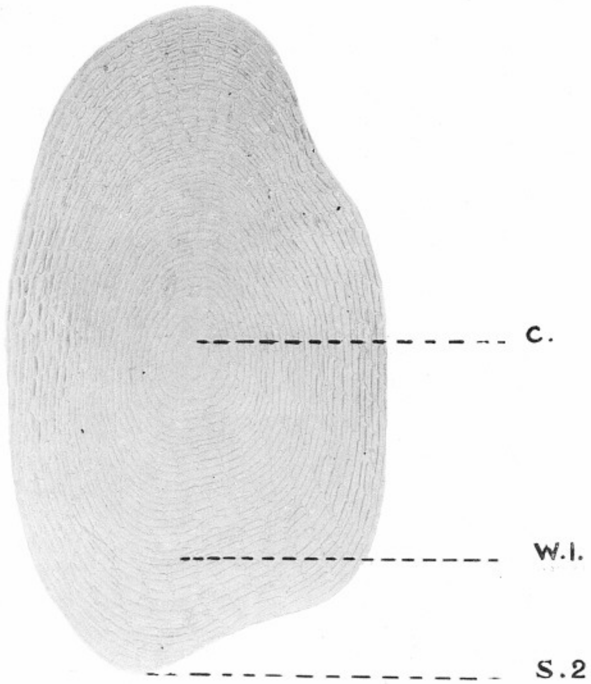

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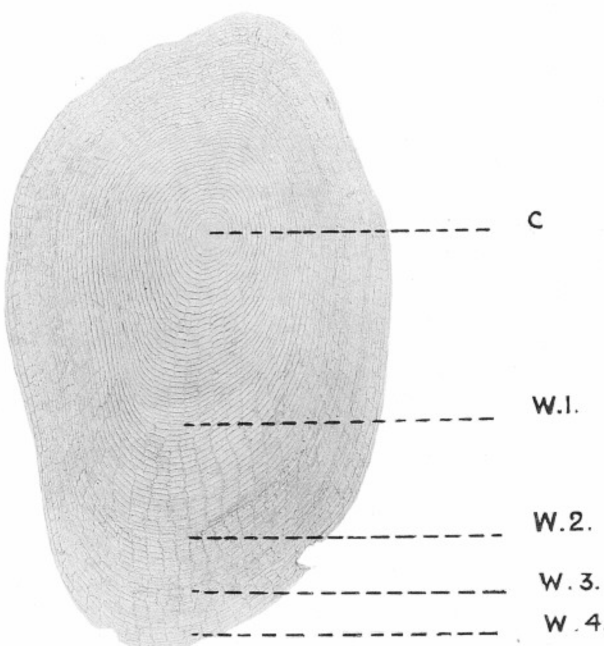

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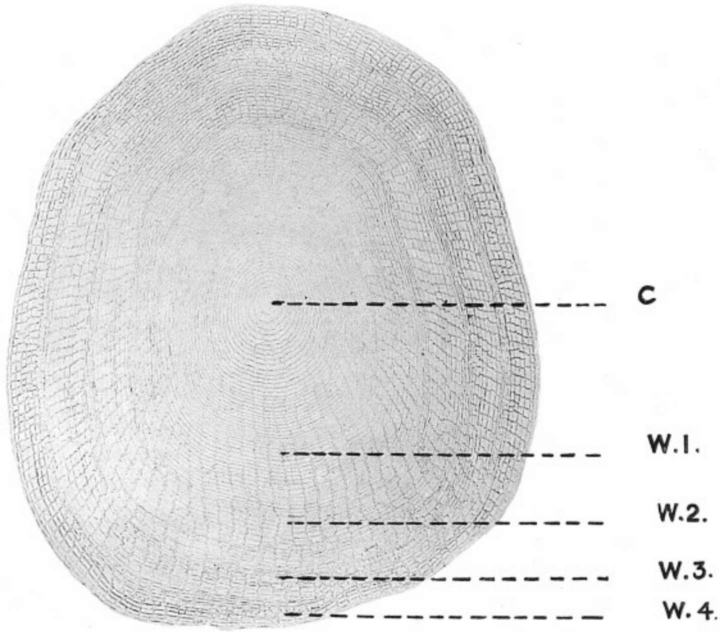

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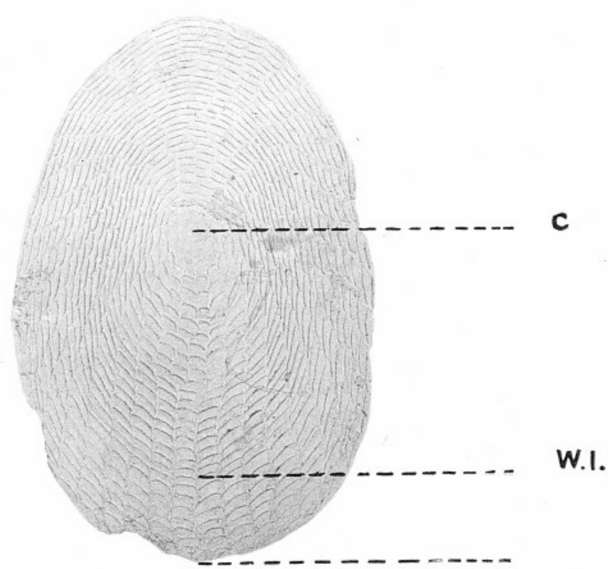

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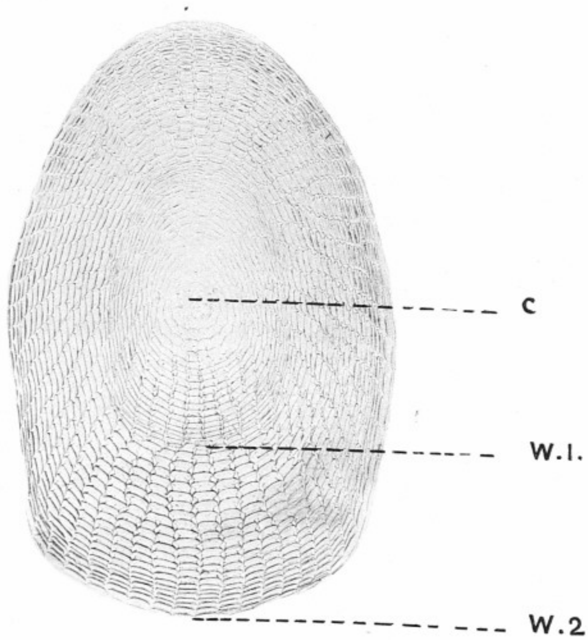

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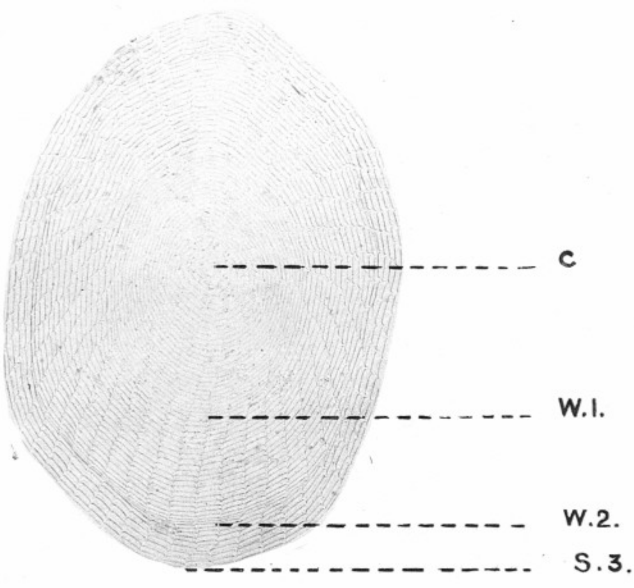

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PLATE III.

Fig. 1.—Scale of Pollack at end of second year. Length of fish, 33·65 cm. (13·25 in.) ; date of capture, May, 1902. This scale has been photographed because it shows extremely little growth for first year, namely, only 18 lines of growth, while that of the preceding scale, for example, shows 28 during this period.

Fig. 2.—Scale of Pollack at commencement of fourth summer, magnified 28 diameters. Length of fish, 44·40 cm. (17·50 in.) ; date of capture, April 30th, 1901 ; age determined, 3 years 6 weeks.

PLATE IV.

Scale of Pollack at commencement of ninth year. Length of fish, 78·74 cm. (31 in.); date of capture, April or May, 1902. This photo-micrograph shows, firstly, how it becomes a much harder task to distinguish the annual rings in the scales of older and larger fish, and, secondly, that the scales of such tend naturally to become broken and disintegrated. Age determined, 8 years 6 weeks.

PLATE V.

Fig. 1.—Scale of *Gadus minutus* in its second summer. Length of fish, 14·30 cm. (5·62 in.); date of capture, July 9th, 1901. This scale shows very clearly the earlier growth of second summer. First year, 37 lines of growth ; second year (early summer), 9 lines of growth. Age determined, 1 year 3 to 4 months.

Fig. 2.—Scale of *Gadus minutus* at end of third winter. Length of fish, 19·05 cm. (7·50 in.) age determined, about 3 years.

PLATE VI.

Fig. 1.—Scale of Whiting in its second summer. Length of fish, 28·50 cm. (11·22 in.) ; date of capture, July 16th, 1901. This scale shows 29 lines of growth for the first year, and 14 lines of growth for the second summer up to July 16th. Age determined, 1 year 4 to 5 months.

Fig. 2.—Scale of Whiting towards end of the fourth year. Length of fish, 34·0 cm. (13·38 in.); date of capture, January 10th, 1902. This scale shows the following lines of growth : first year, 31 ; second year, 21 ; third year, 10 ; fourth year, 9. Age determined, 3 years 10 months.

PLATE VII.

Fig. 1.—Scale of Whiting at commencement of fifth summer. Length of fish, 49 cm. (19·29 in.); date of capture, May 14th, 1901. Age determined, 4 years 2 months.

Fig. 2.—Scale of Coal Fish (*Gadus virens*) in the early summer of second year. Length of fish, 20·22 cm. (8 inches). This scale shows very clearly the early growth of second summer.

PLATE VIII.

Fig. 1.—Scale of Haddock at commencement of third summer. Length of fish, 26·25 cm. (10·33 in.); date of capture, May 10th to 15th, 1901. This scale shows 21 lines of growth for the first year, and 20 lines of growth for the second year. Age determined, 2 years.

Fig. 2.—Scale of Norwegian Whiting Pollack (*Gadus Esmarkii*) in its third summer. Length of fish, 19·05 cm. (7·50 in.); date of capture, August 27th, 1900. Age determined, 2 years 3 to 4 months.

As to the photo-micrographs, Figures 2, 3 and 4, Plate I., were taken by myself ; the remainder are the work of Mr. L. E. Sexton, Plymouth, and Mr. A. Flatters, Manchester.