autumn. From observations made on the breadth of the sclerites at the scale edge he finds that the course of the growth of the scale follows that of the fish — in other words, between the two spurts of growth, shown on the scale by wide sclerites, there will occasionally occur on the scale one or a few narrower sclerites which, by GRAHAM's criterion for the recognition of the second narrow (= winter) ring, will automatically be given the status of such a ring. Conversely the determination of the mean and the range of the number of sclerites to be expected in the first year zone would avoid, in many cases (e.g. in Sample 1) the classing in the 0-group of fish obviously older than one year. Perhaps a similar rigid method applied to the scales of Codling from a region — such as Faroe Bank — of very rapid growth would afford aids for the selection of criteria for other regions. A glance at some of the scale tracings reproduced in this paper is sufficient to show that for the scales of some Codling no precise method of telling the age is possible. In using GRAHAM's method it is obvious that the mensuration will require to be most precise, and the lines on the tracings very thin, since the transition from e.g. the second narrow (= winter) to the third wide (= summer) zone is to be located at a position on the scale where there are three narrow sclerites whose combined width is exceeded (by three sclerites in the succeeding wide zone) by only one fourth. Where there are two comb nations of sclerites giving equal values for the minimum combined width the outermost was consistently selected by GRAHAM. It may be suggested that, to avoid over-shooting the actual winter mark by one or two sclerites, it would be better to place the narrow ring at the narrowest sclerite of these four or six sclerites (as the case may be). This is important if intermediate-age sizes are to be calculated.

The author has removed a pre-existing possibility of complication by determining that autumn-spawning Cod make but a trivial contribution to the stock. Perhaps, however, his deductions bearing on the identity of his various samples tend rather to discount overmuch the possibility of long-distance migration and interchange.

A welcome feature of this paper is a co-operative section on the relevant hydrography of the waters of this area (by J. R. LUMBY). This enables GRAHAM to correlate the secondary spurt of codling growth in late autumn with maximum temperature of the bottom water. H. T.

MICHAEL GRAHAM. Studies of Age-Determination in Fish. Part II. A Survey of the Literature. Min. of Agric. and Fisheries, Fishery Invest., Ser. II, Vol. XI, No. 3, 1928. London, 1929.

The biological study of a fish is greatly facilitated where a ready and accurate means of age-determination exists in one or other of the lime-impregnated structures. Unfortunately, as the author of the above compilation of critical reviews shows, workers on age-determination in fishes have reached results which are often inconclusive or even contradictory of each other. He has therefore carried through the task of scanning the literature on the subject, rejecting such work as seems to be founded on unsubstantial grounds, and, by taking the "greatest common measure"

of the residue (some 70 papers are accepted as supporting their theses with sufficiently plausible data) attempting to enunciate the facts so far established. With these facts in view an hypothesis is then conceived of the metabolic mechanism at work in forming periodic markings in the skeletal structures.

It is difficult, in constructing a synoptic work such as that under review, to preserve throughout any great simplicity of style, or to guide the reader easily among the rapid changes of topic. As Mr. GRAHAM has adopted the method of summarising the papers in chronological order, section A. (pp. 5—34 of his review) may best be regarded as a highly useful work of reference. The reader may with advantage commence with sections B.—F. (pp. 35—43) which discuss, with full references to the detail in Section A., the evidence for the validity of the methods of age-determination, the relation of scale-size to fish-size, and the factors which might be expected to affect scale structure.

Experienced workers on age-determination of fishes will agree with WALTER (quoted on p. 7 of GRAHAM's paper) that "the search for and determination of constant laws is particularly difficult". The zoned scale (or other skeletal part) of even those species of fish most amenable to age-determination does not always clearly depict the correct age. Two reasons for this are the occasional lack of clearness of the so called annual rings and the intervention of varying numbers of "false" rings which are at times indistinguishable (by eye inspection) from annual rings. Some of the authors referred to by GRAHAM state baldly that in practice the two types of rings can be distinguished. In other cases some evidence is given as to how the distinction is to be made. For instance, the use of polarised light in examining scales has been advocated, but, as far as one can judge, has not succeeded in being established as routine technique. The fact seems to be — and GRAHAM from his study of the literature agrees — that although it may be the normal thing for winter conditions to cause a visible check in scale (etc.) growth, the fish may at one time or other during its season of more rapid scale growth experience a period of physiological stress, which can in extreme cases parallel the effect of real winter conditions. Adventitious means of differentiating false from true rings must be found if the worker is to avoid guess-work. GRAHAM himself has elaborated a technique which, within certain limits, enables him to determine what are the true rings in the case of the codling scale. This he has done since he finds, in the cod in particular, that from his historical study of the validity of the methods used in age-determination, there is no convincing evidence (presumably as to the age-determination of an individual fish being correct). As his study of the literature was occasioned chiefly owing to the difficulty of interpreting cod scales, which are more difficult to read than are those of certain other species, it is perhaps natural that he should stress the indeterminate nature of the general evidence for validity. This he has surveyed under five headings:— (1) Agreement (of scale etc. reading) with Petersen's method; (2) the seasonal record (obtained by observation of the markings at the scale edge); (3) the observation of a stock of fish over a period of years, and "marked" scales; (4) marking experiments and (5) tank or pond experiments with fish of known age.

With regard to certain species the reviewer thinks the case for validity has been established more satisfactorily than is indicated in GRAHAM's paper, and may be pardoned if he briefly particularises in the case of haddock, for which evidence has been adduced under all of heads 1—5 above. The ideal case under (1) will be found on p. 8 of a paper[1]) published since GRAHAM made his study. There are detailed the non-overlapping size-frequency distributions of South Iceland haddock of the second, third and fourth years. All the fish were scale-aged, and not only gave the age to be anticipated from Petersen's method, but, with respect to heading (2) above, all were showing fresh unchecked summer growth (i.e. had wide sclerites at the scale margin). Under heading (3) it was found that the dominant broods were those found to be dominant during the previous year. In this case then every individual fish showed the correct scale age. The proof is absolute. But it must be admitted that, in areas where haddock grow more slowly, a certain amount of overlapping occurs at the boundaries of (or even throughout) the size-frequency distribution series. Even so we arrive at almost the same result. We find that the scales give readings in agreement with those to be anticipated from the use of Petersen's method at and near the modal sizes of the distribution series, and that as we go forward from each modal size we find a diminishing number of scales (reading, say 1+) and an increasing number of fish reading one year more (2+). It will be seen that the possibility of making erroneous readings is trivial — in the case of the North Sea haddock it is, in fact, almost nil. If the dominant broods have been followed over a period of years, and retain their relative degrees of frequency year after year, we are secure in our method, and can define the positions in which certain false rings (e.g. that occurring in the first summer) may crop up. Admittedly the evidence for the validity of the scale-age determinations of the older fish is more slender than that for the younger and depends above all upon a wide and continuous study of the broods. But since the bulk of a haddock brood is "cropped" before the age of four years is attained an increasing margin of error at this stage would not prejudice the validity of the method for the purpose for which it is used. It may be added that what may be called the capacity for judgment which is developed in any one whose routine work is scale (etc.) age-assessment is not necessarily subject to an important personal error (in favour, say, of a majority reading) — witness the effort to locate (in numbers) the weakly-represented 1921 and 1922 haddock broods at a time when the possibility of almost complete faiture of a brood was not quite realised.

In a review of the literature on age-determination in fishes, then, one feels that the first discrimination to be made might be that between those species which have been continuously studied over at least the major portion of their habitat and those which have, probably in a succession of hands, been studied only locally or intermittently, so that the undoubted value of the perspective view and of sequence is lost. But nearly all the

[1]) H. THOMPSON. General Features in the Biology of the Haddock in Icelandic Waters during the period 1903—1926. (Fish. Bd. for Scot., Sci. Invest. No. V. 1929.)

author's comments on the more striking aspects of the papers summarised in Section A of his paper will meet with approval. One might prefer to have fuller comment in certain cases where cross-implications arise from authors' statements — e.g. the following made by WALTER:—

> "The relative width, that is the size ratios of one to another on a radius, of corresponding true zones of different scales from the same fish is always the same," and
>
> "The relative width of corresponding false zones does not agree in different scales of the same fish".

These statements seem to be contradictory, since the position of a false ring has been experimentally proved to be as fixed in the scale as is that of a true ring.

Tropical fish (SCHNEIDER, p. 14) and fish living in a temperate climate all the year round (MOHR, p. 26) are said to form rings on their scales, probably, one thinks, just as North Sea fish can form false rings during their summer-autumn season. GRAHAM suggests, however, that fish may exhibit an inherent rhythm masking the response to environmental conditions. The suggestion may here be added that ring-formation is the outcome of retardation of anabolic processes, caused normally where winter conditions have to be passed through, but capable of being caused at any time when adverse conditions prevail. The role of varying temperature as a physical factor affecting growth rate is, as is evident from the results quoted from LEA (p. 15) and FRASER (p. 22) quite indirect. The reviewer suggests that there is probably, for each species, a range of temperature over which growth can proceed, and that there may be an optimum temperature at which, other things being equal, growth is fastest. But may the real importance of the temperature factor not lie in the necessity of a certain minimum temperature (possibly varying from region to region) being essential to set in motion the elaboration of fish-food through a chain of organisms? That there should be a lag between the spring rise of temperature and the first evidence of fresh growth on the scale of the fish would not then be surprising. In extreme cases indeed there is no sign of new fish or scale growth before autumn. On account of the possibility of shoal mixing, this fact — that of regional variation in the time of onset of the new year's growth — makes any evidence submitted under heading (2) much less critical than that under headings (1) and (3). GRAHAM points out that absence of simultaneous turnover from narrow to broad sclerites at the scale edge may give rise to some errors of scale-age interpretation, and this is true unless, from comparative biological studies of shoals over a wide area, these errors can be anticipated and avoided. The author animadverts upon the more or less unsatisfactory theories which have been brought forward to explain why sclerite width should vary, and himself elaborates an hypothesis (Section F) with this end in view. His theory does not seem to be so clearly expressed as could be desired, so that it is difficult to estimate its value.

Validity-evidence under (4) above has as is stated been most utilised

in the case of salmon, but, apart from the question of expense, the use of marking is, one feels sure, capable of great and profitable extension in the case of other fish. The evidence is of first-rate importance, as should be that obtained under heading (5) (aquarium experiments). In the latter case, however, as GRAHAM points out, it is difficult to correlate such restricted and mostly unrepeated experimental work as has been done in the past. One agrees with the author that there is room for further experimental work, but it seems that, in order to avoid a repetition of any feeling of doubt as to the comparative value of such work, the conditions under which it takes place should be rigorously controlled. Indeed, aquarium facilities for such work would almost require to be created.

The author's review (Section D) of the theories in connection with the use of scales for calculation of the growth of fish in their earlier years is very adequate. The relative growth rates of fish and their scales are apparently incapable of being correlated by a simple law, but MONASTUIRSKY (p. 31) is quoted as having arrived at a logarithmic formula enabling the size of a fish at any intermediate age to be calculated from that of the scale at the same age if a double correction be made — (a) for the relative disproportion between size of scale and fish at the time of first formation of the former and (b) for the relation (apparently not quite linear) between the subsequent relative growth-rates of scale and fish. It is obvious that in the case of each species for which scales are to be used (as they may most profitably be used) for calculation of growth-rate an extensive series of highly accurate measurements must be taken for the final establishment of the exact relationship between growth of scale and fish. H.T.

MICHAEL GRAHAM. On Methods of Marking Round Fish with an Account of Tests in Aquaria. Ministery of Agriculture and Fisheries. Fishery Invest. Ser. II, Vol. XI, No. 4, 1928. London 1929.

After giving a very interesting account of the main types of fish marks that have been used the author describes a series of very painstaking experiments performed by him at the aquarium of the Dove Marine Laboratory at Cullercoats. His results are of the highest interest for work with marked fish and may be shortly summarized thus; all marks used have a strong tendency to be lost before a year after marking. The best marks are those consisting of two ebonite or silver buttons; and of the three positions in which they have been fastened, the operculum, the base of the dorsals and the upper side of the tail root, the latter two places seem to offer the best possibility of the mark being kept by the fish for an extended period.

The author's experiments were begun as early as 1924 and continued during 3 years on a great number of fish — small cod. They may therefore be looked upon as very trustworthy, although it may be that the keeping-on qualities of all types of marks might have appeared better if the experiments could have been made with larger fish. Those used were about 35 cm. long. The use of such small fish was of course necessitated by practical circumstances and made it possible to keep sufficient numbers to get rational results.