quickly than even the fast-growing Faroe Haddock, but that this advantage is more than lost by the earlier and more pronounced slowing down of rate of growth from about the seventh year. NEEDLER makes a point of the fact that growth in Canadian waters far exceeds that in the deeper portions of the North Sea, although the mean annual temperature of the latter exceeds that of the former. It follows that temperature *per se* is not an absolute factor controlling growth rate. The thesis is still tenable, however, that within areas supporting independent Haddock stock there is for Haddock growth probably an optimum temperature, lying well on the high side of the mean annual temperature. Conversely there is probably a temperature not far above zero where growth effectually ceases. (NEEDLER finds that more than 80 % of the year's growth is put on between Aug. 1st and Nov. 1st, the temperature for the remaining portion of the year being very low.) That the optimum temperature in the North Sea may be higher than in Canadian waters is conceivable if we consider the effect of temperature as two-fold — first, as a physical factor affecting the metabolic processes of the fish, secondly, as a physical factor setting in motion the complex chain of elaboration of fish food from lower organisms, the particular species of which are not the same in the two localities, whose sources of organic and inorganic raw material are different. In short, a slightly lower temperature in one region as compared with another where the raw material for organic growth is scantier or different in type, may engender a more copious or more nutritious food supply and more than counterbalance a possible restraining effect on the sheer metabolic processes of the fish. H. T.

MICHAEL GRAHAM. Studies of Age-Determination in Fish. Part I: A Study of the Growth-Rate of Codling (*Gadus callarias* L.) on the Inner Herring Trawling Ground. Min. of Agric. and Fisheries, Fishery Invest., Ser. II, Vol. XI, No. 2, 1928. London, 1929.

This paper will rank among the most important of those dealing with methods of age-determination of Cod. GRAHAM has examined his subject with meticulous care, envisaging and evaluating (or discounting) all the possible obstacles to the practice of his technique. It is probable that the work of age-determination of any fish (in at least some parts of the habitat of the latter) will ultimately come to have some such mechanical basis as he sets forth. The author's thesis was to attempt, by a rigid method independent of personal judgment, to determine the age of Codling within a circumscribed area of the North Sea. It is a desideratum that, in a study involving the comparison of scales, the average scale used should be from approximately the same part of the body of the fish. The author admits, however, that both by selection at sea and again in the laboratory this ideal was somewhat departed from. In a repetition of such work this fault would be remediable with, most probably, the removal of some of the difficulties GRAHAM encountered in making his deductions. To take an example, by no means isolated, we find that the scale from a 30 cm. fish (No. 124, Fig. 51) has been so selected that it is larger than one from a 56 cm. fish (No. 87). In an allied fish (Haddock) this contingency is well

outside the range of possibility if scales be taken from a selected — but not too restricted — part of the body of the fish. While such a selection of scale from the larger fish may not, as the author thinks from a study of a series of scales from different body parts, impair the determination of age, it is probable that the consistent selection of one of the largest scales would facilitate such determination and reduce the number of older fish which (e.g. No. 130 — size 59 cm.) had to be classed in the 0-group. Certainly, as he admits, the curve (Fig. 11) expressing the relationship between size of fish and scale would, in the upper portion, take a different course. The formulae derived to express the relationship and to enable fish size at any intermediate age to be worked out are, however, restricted by him to fish sizes 15—34, where scale selection was most uniform, and where the relationship is roughly linear. One of the highest merits of GRAHAM's method is that, by a simple technique of reproducing for scrutiny a picture of the sclerite-widths of each scale used by him, future detailed use may be made by others of his work. Inevitably of course there are lost any possibly valuable optical effects such as are seen in the scale under magnification. Age-determination is made, not directly from the scale, but from this replica of its most essential features. In his search for mechanical methods of interpreting age therefrom the author has, by a process of trial and error, found that by adopting certain criteria, whose limitations he specifies, there is a very high degree of probability that the majority of the fish will be correctly "aged". This is established since the age of the majority of the fish in his samples was known, these fish belonging to the 1923 brood and being followed year by year till 1926, when, at the age of about three and a half years, it was certain that they were being utilised commercially. That no fish in the majority groups is incorrectly aged is not claimed, and indeed an inspection of the scale tracings suggests that, save in the case of some of the larger fish included in these groups, there can be no other age than that indicated. So far then the method is unique in that it provides a means, independent of personal judgment or bias, of determining the approximate proportions of the numbers of the dominant year-groups of Codling in a certain portion of the North Sea. There remains over a minority group, consisting of fish of genuine non-dominant broods, and others of the dominant brood whose age has been incorrectly determined by the method, which as it stands does or can make no use of this group. This is a drawback, and one would suggest that the method, to the extent in which it has proved infallible, be used for the deduction of what might be called secondary criteria, the use of which would allow of a proportion of the minority group being correctly aged. For instance it should be profitable to determine the range and the mean number of sclerites in fish known to be one and two years of age, and possible to tie down the position of the "false" narrow ring that appears to occur at times in the second year zone of the scale. GRAHAM indeed produces evidence which would suggest that such a false ring may occasionally be looked for. He shows that, at least in some years, the growth cycle proceeds from a period of stasis in the three winter months to a period of rapid growth in early summer, followed by a decline of rate of growth towards autumn and a second period of rapid growth in late

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"