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Abnormal Vertebræ in Herrings.

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With 3 Figures in the Text.

An important part of recent investigations on herrings at Plymouth has been the collection of statistical data on the number of vertebræ, and when this report was written a total of 6869 fishes had already been examined with regard to this character. In the case of each of 105 fishes, however, the true number of vertebræ could not be stated with confidence, owing to marked irregularities in one or more vertebræ.* These abnormal specimens are of more than passing interest. The abnormalities themselves are such that it would be well worth while to make a careful morphological study of " fresh " specimens to determine the extent to which nerves and muscles are affected. The determination of the distribution of abnormalities along the vertebral column suggests a possible explanation of the way in which they may have arisen. Moreover, there remains the question as to how the abnormal vertebræ should be counted when endeavouring to ascertain the true total number of vertebræ for statistical or genetic purposes. In the paragraphs which follow, the 105 cases of abnormality are described and their significance both in numbers and position discussed, but it should be remembered that all observations and measurements were made on dried skeletons, which had been prepared by boiling and cleaning.

The Characters of the Abnormalities.

In each of the skeletons under review, abnormality is localised in one or more distinct vertebral elements, which may be classified according to their features. The summary in Table 1 shows that a total of 142 such elements were found in the 105 skeletons obtained, but that generally a single skeleton had only one abnormal element.

* *Orton* (**3**) has given a detailed description of similar cases of irregularity obtained during his investigations on herring at Plymouth in 1914.

TABLE 1.

No. of abnormal elements per skeleton	1	2	3	5	7	Totals.
Number of skeletons	82	17	3	2	1	105 skeletons.
Total of abnormal elements	82	34	9	10	7	142 abnormal elements.

In the following description of the arbitrary classes into which the abnormal elements have been grouped, sufficient data have been included to indicate the relative frequency of occurrence of the several classes.

Class 1.

A typical vertebral element of this class has the appearance of an incipient " double " vertebra. It bears an extra pair of hæmal and neural spines arising from the median portion of the centrum, where there is a more or less distinct vertical ridge. There is, however, no suture or epiphysial growth such as occurs between two normal vertebræ. In abnormal elements from the anterior region of the body there is also an associated doubling of the epineural, pleural, and epipleural bones. In length these " double " vertebræ vary from 1 to $1\frac{1}{2}$ times that of normal adjacent vertebræ. In the cases included in this class a gradation can be noted, from those in which only an extra neural arch and an extra hæmal arch occur with no distinct ridge to the centrum, to others which have almost the appearance of two normal, though undersized, vertebræ (see Fig. 1A).

In 57 of the total of 105 skeletons the abnormal elements are exclusively of this class, and in 52 instances a single skeleton exhibits a single abnormal element. In a further 6 skeletons an abnormality of this class is accompanied by an irregularity of another class. Of the total of 142 abnormal elements examined, 71 are included under Class 1.

Class 2.

Abnormal elements of this class are analogous in structure to those of Class 1, but are triplicate in formation. The length of the compound element is less than twice that of normal vertebræ. In 14 skeletons these triplicate vertebræ are exclusively present, while in 3 other cases they occur with other abnormal elements.

Class 3.

Compound vertebræ of apparent " quadruple " formation occur in 3 skeletons, but in no case does the length of the element exceed twice that of normal vertebræ (see Fig. 1C).

Class 4.

In 21 skeletons interesting bilateral asymmetry occurs. One side of an ordinary-sized vertebra has the structure described for either Class 1 or Class 2, while the other appears normal. Occasionally one side is of Class 1 and the other of Class 2.

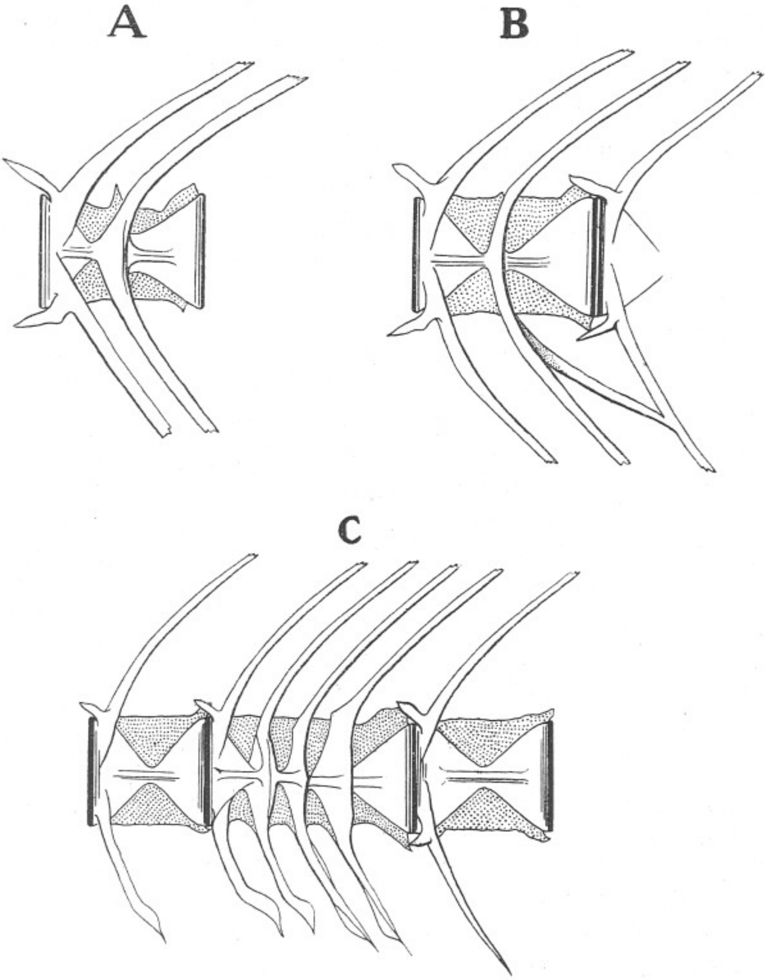

FIG. 1.—A. Typical example of abnormal vertebra of Class 1.
33rd vertebra of a herring 29 cm. in length.

B. Abnormalities of Classes 1 and 5 occurring together.
21st vertebra of a herring 22 cm. in length.

C. Abnormality of Class 3.
Fusion of vertebræ 25–28 incl.; in a herring 28 cm. long.
Vertebræ 24 and 29 are normal.

Class 5.

This class was created to include a number of minor abnormalities which were considered to be of no immediate importance.

(*a*) One of the neural or hæmal spines of a single vertebra or of one of the components of a " double " vertebra, becomes attached obliquely to the neural or hæmal spine of the opposite side of the preceding vertebra or vertebral component. The fellows of these spines remain single and unattached (see Fig. 1B).

(*b*) A slight twisting of a part of the vertebral column involving several adjacent vertebræ.

(*c*) Minor irregularities of certain vertebræ which may be due to mechanical injury at some earlier stage in the life-history.

In most instances these minor irregularities occur in association with those of the earlier classes, but in any case there is no visible differentiation of the centrum suggesting a compound formation.

In a short essay on the " numerical signification of fused vertebræ," Schmidt (**4**) discussed the question as to how certain peculiar vertebral elements in reared trout should be counted in his investigations on the inheritance of the number of vertebræ. In each of 8 samples of the offspring from diallel crossings, he found a number of individuals (average ca. 10%) in which the vertebra fifth from the end of the tail showed a peculiarity impossible to ignore and which placed him in doubt as to whether he was dealing with a single or a double vertebra. He was able to show, however, that the average number of vertebræ for the " abnormal " specimens in the 8 samples closely approached that for the " normal " specimens if a numerical value of $1\frac{1}{2}$ was assigned to the irregular vertebra. On this evidence Schmidt advanced the theory that " vertebrate animals can realise fractional parts of vertebræ, but it is evident that such individuals are numerically inferior to what we above called normal individuals. In reality the former are just as normal as the latter. In both cases it is the individual's genetic structure in connection with its environment in the sensitive period, which is deciding the total realised ; but it seems as if whole numbers in such organs as vertebræ are more easily realised than fractional parts."

We have carried out some counting trials with our abnormal herrings and the results have proved instructive. It will be seen from Table 2 that if we count the irregular vertebræ as single units the average number of vertebræ for the 95 specimens examined is 54·40, the variates ranging from 48 to 57. These values are much lower than those obtained from

" normal " specimens. If, however, we assume that the " abnormal " vertebræ each represent several whole vertebræ and assign to them an equivalent numerical value, then the average closely approaches that for the " normals."

For the third counting trial all specimens which showed more than one vertebral irregularity were excluded in order that the material upon which the count was to be made should be such that Schmidt's theory and method might reasonably be applied to it. But it is clear from

TABLE 2.

Total No. of Vertebræ.	No. of " Normal " Skeletons.	No. of " Abnormal " Skeletons. Abnormal element counted as:	
		One Vertebra.	x Whole Vertebræ.
48	—	1	—
49	—	—	—
50	—	1	—
51	—	2	—
52	—	3	—
53	3	5	2·5*
54	70	26	3
55	1921	46	24
56	4157	10	47·5*
57	595	1	16
58	18	—	2
Totals	6764	95	95
Arith. mean.	55·79	54·40	55·82
	Difference from 55·79	—1·39	+·03

Table 3 that the adoption of the numerical value of $1\frac{1}{2}$ for a double vertebra produces a less satisfactory " fit " to the normal average than that resulting from the use of the value of 2.

The fact that in the reared trout abnormality was localised in a particular vertebra in the tail region is worthy of notice. If for the moment it be conceded that fractional parts of vertebræ can actually be realised, the

* In some skeletons it is not possible to decide upon the exact number of vertebrae. In the case of a skeleton whose whole total number appears to be either 53 or 54, the entry of $\frac{1}{2}$ is made to each of the variants 53 and 54.

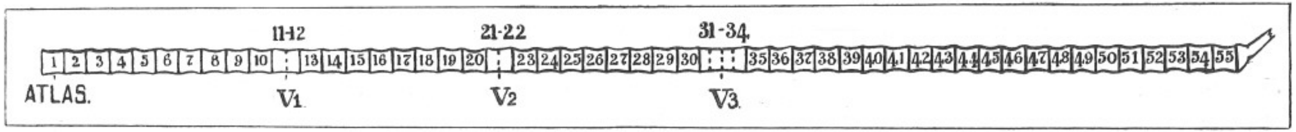

FIG. 2.—Diagram to illustrate method of defining the serial position of abnormal vertebral elements.

V_1. Abnormality of Class 1 (fusion of vertebræ 11 and 12).
V_2. Abnormality of Class 1 (fusion of vertebræ 21 and 22).
V_3. Abnormality of Class 3 (fusion of vertebræ 31–34 inclusive).

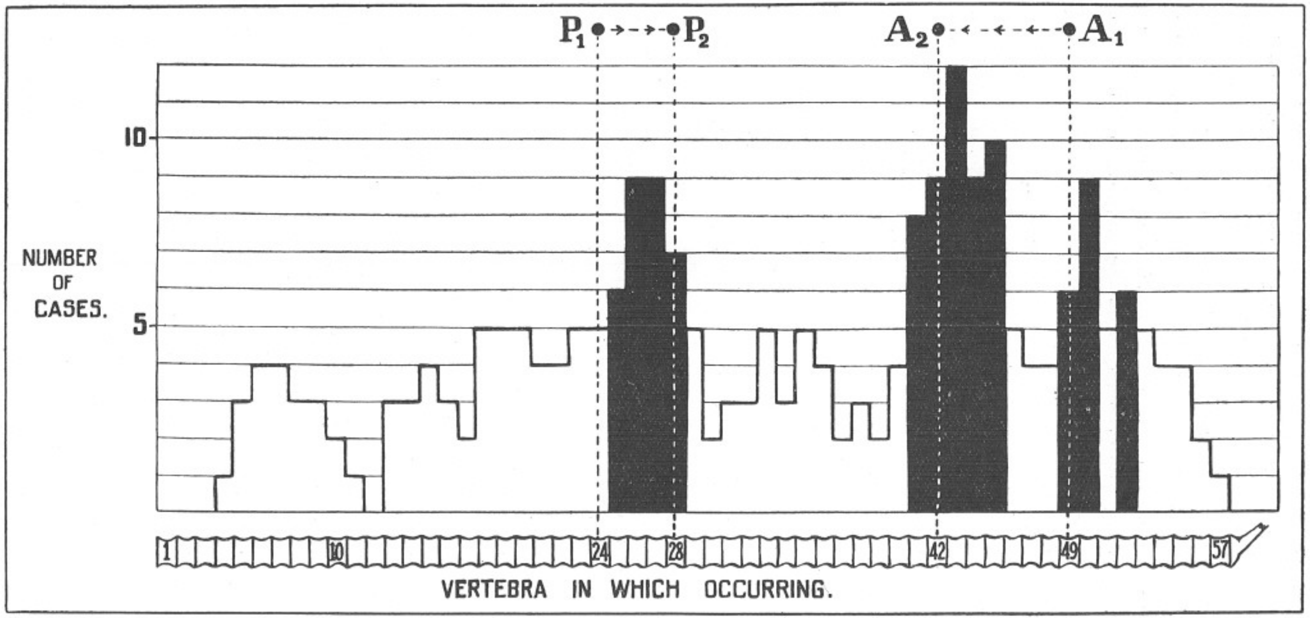

FIG. 3.—Distribution of abnormality along vertebral column. Diagrammatic representation of data summarised in Table 4 (p. 516). Vertebræ involved on more than five occasions are blocked in black.

A_1. Initial position of anus in post-larvæ. } *vide* Lebour (2)
A_2. Final ,, ,, in young fish.

P_1. Initial position of pelvics in post-larvæ. } *vide* Lebour (2)
P_2. Final ,, ,, in young fish.

localisation of the abnormality suggests that one particular vertebra is alone able to express itself in a broken number. In the herring, cases of irregularity have been observed in almost every vertebra throughout the vertebral column, but there is a distinct indication that some parts

TABLE 3.

Total No. of Vertebræ.	No. of Skeletons. "Double" element counted as: 1 Vertebra.	$1\frac{1}{2}$ Vertebræ.	2 Vertebræ.
52	1	—	—
52·5	—	1	—
53	2	—	1
53·5	—	2	—
54	15	—	2
54·5	—	15	—
55	32	—	15
55·5	—	32	—
56	7	—	32
56·5	—	7	—
57	—	—	7
57·5	—	—	—
Total	57	57	57
Arith. mean.	54·74	55·24	55·74
Difference from "normal" mean (55·79)	−1·05	−·55	−·05

are more susceptible than others. Table 4 and Fig. 3 express the relative frequency of abnormality for each vertebra along the vertebral column. To obtain these data, the total number of vertebræ in each skeleton was ascertained after making the appropriate numerical allowance for the number of whole vertebræ apparently involved in each abnormality, and the serial position of each abnormally presented vertebra was noted. The method of recording will be clear after reference to the hypothetical case shown in Fig. 2. It will be observed in Figure 3 that while vertebræ, Nos. 1, 2, 3, and 12 are the only ones in which abnormality has as yet not been seen, twelve of the vertebral series have each been involved on more than five occasions. The distribution of these twelve vertebræ is of especial interest: four of them are consecutive, forming the group, vert. 25–28, inclusive, and the remaining eight occur in the region, vert. 41–52. Now in Fig. 3 we have indicated the initial and final positions of the anus (A_1 and A_2) and of the pelvic fins (P_1 and P_2) with respect to the vertebræ during the early life of the herring, as determined by Lebour (**2**, p. 451). These positions fall within the range of the twelve vertebræ just enumerated. In view of the limited number of skeletons examined it would be obviously unwise to attach definite significance to this coincidence in position, but we may at least suspect that there is some connection between the formation of abnormal vertebral elements and the differential growth of the post-larva. It would appear from Lebour's results, however, that the number of myotomes and hence, presumably, the number

TABLE 4.

Number of cases of Abnormality.	Serial numbers of Vertebrae involved.		Totals exclusive of 24–28, and 43–49.	Totals 24–28, and 43–49 only.
0	*1, 2. 3, 12.*		4	
1	*4, 11, 57.*		3	
2	*10, 17, 30, 37, 39, 56.*		6	
3	*5, 8, 9, 13, 14, 16, 31, 32, 34, 38.*		10	
4	*6, 7, 15, 21, 22, 36, 40, 54, 55.*	*47, 48.*	9	2
5	*18, 19, 20, 23, 29, 33, 35, 51, 53.*	*24, 46.*	9	2
6	*52.*	*25, 49.*	1	2
7		*28.*		1
8	*41.*		1	1
9	*50.*	*26, 27, 42, 44.*	1	4
10		*45.*		1
12		*43.*		1

of vertebræ, is fixed before the "migration" of the anus and pelvics begins; so that our abnormal vertebral elements would thus have to be considered as the result of partial coalescence of several whole vertebræ—a proposition already regarded as likely from other considerations.

It is not suggested that the movements of the anus and pelvics are alone concerned in the formation of abnormalities, for while it is true that irregularities most frequently occur in the region of the anal and pelvic movement, cases occur elsewhere in numbers. Lebour states that the dorsal fin which lies originally over the region, vert. 33–42/43 comes to lie over vert. 26–34/35. The total range of this movement fills the gap between P_1 and P_2, and A_1 and A_2. Then posteriorally the anal fin moves with the anus. Anteriorally the pectorals find attachment, and in Fig. 3 there is a marked peak at vert. 6–7. The suggestion is rather that the whole effect of differential growth should be taken into account.

Finally, it is interesting to note that Gemmill (**1**, p. 52 footnote) refers to a statement from Hubrecht (*Klassen u Ordn.* 6, *Abt.* 1–3, p. 60) that in shark-like fishes, pathological coalescence of vertebræ is commonest at the places of connection of the paired fins with the vertebral column.

LITERATURE.

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