# SCIENCE:

*A WEEKLY NEWSPAPER OF ALL THE ARTS AND SCIENCES*

PUBLISHED BY

N. D. C. HODGES,

47 LAFAYETTE PLACE, NEW YORK.

SUBSCRIPTIONS.—United States and Canada................$3.50 a year.

Great Britain and Europe................. 4.50 a year.

Communications will be welcomed from any quarter. Abstracts of scientific papers are solicited, and one hundred copies of the issue containing such will be mailed the author on request in advance. Rejected manuscripts will be returned to the authors only when the requisite amount of postage accompanies the manuscript. Whatever is intended for insertion must be authenticated by the name and address of the writer; not necessarily for publication, but as a guaranty of good faith. We do not hold ourselves responsible for any view or opinions expressed in the communications of our correspondents.

Attention is called to the "Wants" column. All are invited to use it in soliciting information or seeking new positions. The name and address of applicants should be given in full, so that answers will go direct to them. The "Exchange" column is likewise open.


## RELATIONS OF TEMPERATURE TO VERTEBRÆ AMONG FISHES.[1]

IT has been known for many years that in certain groups of fishes the northern or cold-water representatives have a larger number of vertebræ than those members which are found in tropical regions. To this generalization, first formulated by Dr. Gill in 1863, we may add certain others which have been more or less fully appreciated by ichthyologists, but which for the most part have never received formal statement. In groups containing fresh-water and marine members, the fresh-water forms have in general more vertebræ than those found in the sea. The fishes inhabiting the depths of the sea have more vertebræ than their relatives living near the shore. In free-swimming pelagic fishes the number of vertebræ is also greater than in the related shore fishes of the same regions. The fishes of the earlier geological periods have for the most part numerous vertebræ, and those fishes with the low numbers (24 to 26) found in the specialized spiny-rayed fishes appear only in comparatively recent times. In the same connection we may also bear in mind the fact that those types of fishes (soft-rayed and anacanthine) which are properly characterized by increased numbers of vertebræ predominate in the fresh waters, the deep seas, and in Arctic and Antarctic regions. On the other hand, the spiny-rayed fishes are in the tropics largely in the majority.

In the present paper, I wish to consider the extent to which these statements are true and to suggest a line of explanation which covers all these generalizations alike.

For the purpose of this discussion we may assume the derivation of species by means of the various influences and processes, for which, without special analysis, we may use the term "natural selection." By the influence of natural selection, the spiny-rayed fish, so characteristic of the present geological era, has diverged from its soft-rayed ancestry.

[1] Abstract of a paper by David Starr Jordan, president of Leland Stanford, Jr., University (Proceedings U.S. National Museum, XIV., 107).

The influences which have produced the spiny-rayed fish have been most active in the tropical seas. It is there that "natural selection" is most potent, so far as fishes are concerned. The influence of cold, darkness, monotony, and restriction is to limit the direct struggle for existence, and therefore to limit the resultant changes. In general the external conditions most favorable to fish life are to be found in the tropical seas, among rocks and along the coral reefs near the shore. Here is the centre of competition. From conditions otherwise favorable to be found in Arctic regions, the majority of competitors are excluded by their inability to bear the cold. In the tropics is found the greatest variety in surroundings, and therefore the greatest variety in the possible adjustments of series of individuals to correspond with these surroundings.

The struggle for existence in the tropics is a struggle between fish and fish, and among the individuals of a very great number of species, each one acquiring its own peculiar points of advantage. No form is excluded from competition. No competitor is handicapped by loss of strength on account of cold, darkness, foul water, or any condition adverse to fish life.

The influences which serve as a whole to make a fish more intensely and compactly a fish, and which tend to rid it of every character and every organ not needed in fish life, should be most effective along the rocks and shores of the tropics.

For this process of intensification of fish-like characters, which finds its culmination in certain specialized spiny-rayed fishes of the coral reefs, we may conveniently use the term "ichthyization."

If ichthyization is in some degree a result of conditions found in the tropics, we may expect to find a less degree of specialization in the restricted and often unfavorable conditions which prevail in the fresh waters, in the cold and exclusion of the polar seas, and especially in the monotony, darkness, and cold of the oceanic abysses where light can not penetrate and where the temperature scarcely rises above the freezing point.

An important factor in ichthyization is the reduction of the number of segments or vertebræ, and a proportionate increase in the size and complexity of the individual segment and its appendages. If the causes producing this change are still in operation, we should naturally expect that in cold water, deep water, dark water, fresh waters, and in the waters of a past geological epoch the process would be less complete and the numbers of vertebræ would be larger. And this, in a general way, is precisely what we find in the examination of a large series of fishes.

If this view is correct, we have a possible theory of the reduction in numbers of vertebræ as we approach the equator. It should, moreover, not surprise us to encounter various modifications and exceptions, for we know little of the habits and scarcely anything of the past history of great numbers of species. The present characters of species may depend on occurrences in the past concerning which even guesses are impossible.

It may be taken for granted that the ancestry of the various modern types of bony fishes is to be sought among the Ganoids. All the fossil forms in this group have a notably large number of vertebræ. The few now living are nearly all fresh-water fishes, and among these, so far as known, the numbers range from 65 to 110.

Among the *Teleostei* or bony fishes, those which first appear in geological history are the *Isospondyli*, the allies of the salmon and herring. These have all numerous vertebræ, small in size, and none of them in any notable degree modified or specialized. In the northern seas *Isospondyli* still exceed all other fishes in number of individuals. They abound in the depths of the ocean, but there are comparatively few of them in the tropics.

The *Salmonidæ* which inhabit the rivers and lakes of the northern zones have from 60 to 65 vertebræ. The *Scopelidæ*, *Stomiatidæ*, and other deep-sea analogues have from 40 upwards in the few species in which the number has been counted. The group of *Clupeidæ* is probably nearer the primitive stock of *Isospondyli* than the salmon are. This group is essentially northern in its distribution, but a considerable number of its members are found within the tropics. The common herring ranges farther into the Arctic regions than any other. Its vertebræ are 56 in number. In the shad, a northern species which ascends the rivers, the same number has been recorded.

The sprat and sardine, ranging farther south, have from 48 to 50, while in certain small herring which are strictly confined to tropical shores the number is but 40. Allied to the herring are the anchovies, mostly tropical. The northernmost species, the common anchovy of Europe, has 46 vertebræ. A tropical species has 41 segments. There are, however, a few soft-rayed fishes confined to the tropical seas in which the numbers of vertebræ are still large, an exception to the general rule for which there is no evident reason unless it be connected with the wide distribution of these almost cosmopolitan fishes. In a fossil herring-like fish from the Green River shales, I counted 40 vertebræ; in a bass-like or serranoid fish from the same locality 24, these being the usual numbers in the present tropical members of these groups.

The great family of *Siluridæ* or catfishes seems to be not allied to the *Isospondyli*, but a separate offshoot from another ganoid type. This group is represented in all the fresh waters of temperate and tropical America, as well as in the warmer parts of the Old World. One division of the family, containing numerous species, abounds on the sandy shores of the tropical seas. The others are all fresh-water fishes. So far as the vertebræ in the *Siluridæ* have been examined, no conclusions can be drawn. The vertebræ in the marine species range from 35 to 50; in the North American forms from 37 to 45, and in the South American fresh-water species, where there is almost every imaginable variation in form and structure, the numbers range from 28 to 50 or more.

The *Cyprinidæ*, confined to the fresh waters of the northern hemisphere, and their analogues, the *Characinidæ* of the rivers of South America and Africa, have also numerous vertebræ, 36 to 50 in most cases. I fail to detect in either group any relation in these numbers to surrounding conditions.

In general, we may say of the soft-rayed fishes that very few of them are inhabitants of tropical shores. Of these few, some which are closely related to northern forms have fewer vertebræ than their cold-water analogues. In the northern species, the fresh-water species, and the species found in the deep sea, the number of vertebræ is always large, but the same is true of some of the tropical species also.

Among the spiny-rayed fishes the facts are more striking. Of these, numerous families are chiefly or wholly confined to the tropics, and in the great majority of all the species the number of vertebræ is constantly 24, 10 in the body and 14 in the tail ($10 + 14$). In some families in which the process of ichthyization has gone on to an extreme degree, as in certain *Plectognath* fishes, there has been a still further reduction, the lowest number, 14, existing in the short inflexible body of the trunkfish, in which the vertebral joints are movable only in the base of the tail. In all these forms, the process of reduction of vertebræ has been accompanied by specialization in other respects. The range of distribution of these fishes is chiefly though not quite wholly confined to the tropics.

A very few spiny-rayed families are wholly confined to the northern seas. One of the most notable of these is the family of viviparous surf fishes, of which numerous species abound on the coasts of California extending to Oregon, and Japan, but which enter neither the waters of the frigid nor the torrid zone. These fishes seem to be remotely connected with the *Labridæ* of the tropics, but no immediate proofs of their origin exist. The surf fishes have from 32 to 42 vertebræ, numbers which are never found among tropical fishes of similar appearance or relationship.

The case of the *Labridæ*, in which the fact was first noticed, has been already mentioned. Equally striking are the facts in the great group of *Cataphracti*, or mailed-cheek fishes, a tribe now divided into several families, diverging from each other in various respects, but agreeing in certain peculiarities of the skeleton. Among these fishes the family most nearly related to ordinary fishes is that of *Scorpænidæ*. This is a large family containing many species, fishes of local habits, swarming about the rocks at moderate depths in all zones. The species of the tropical genera have all 24 vertebræ. Those genera chiefly found in cooler waters, as in California, Japan, Chili, and the Cape of Good Hope, have in all their species 27 vertebræ, while in the single arctic genus there are 31. An antarctic genus bearing some relation to *Sebastes* has 39.

Allied to the *Scorpænidæ*, but confined to the tropical or semitropical seas, are the *Platycephalidæ*, with 27 vertebræ, and the *Cephalacanthidæ*, with but 22. In the deeper waters of the tropics are the *Peristediidæ*, with 33 vertebræ, and extending farther north, belonging as much to the temperate as to the torrid zone, is a large family of the *Triglidæ*, in which the vertebræ range from 25 to 38.

The family of *Agonidæ*, with 36 to 40 vertebræ, is still more decidedly northern in its distribution. Wholly confined to northern waters is the great family of the *Cottidæ*, in which the vertebræ ascend from 30 to 50. Entirely polar and often in deep waters are the *Liparididæ*, an offshoot from the *Cottidæ*, with soft, limp bodies, and the vertebræ 35 to 65. In these northern forms there are no scales, the spines in the fins have practically disappeared, and only the anatomy shows that they belong to the group of spiny-rayed fishes. In the *Cyclopteridæ*, likewise largely arctic, the body becomes short and thick, the backbone inflexible, and the vertebræ are again reduced to 28. In most cases, as the number of vertebræ increases, the body becomes proportionally elongate. As a result of this, the fishes of arctic waters are, for the most part, long and slender, and not a few of them approach the form of eels. In the tropics, however, while elongate fishes are common enough, most of them (always excepting the eels) have the normal number of vertebræ, the greater length being due to the elongation of their individual vertebræ and not to their increase in number.

In the great group of blenny-like fishes the facts are equally striking. The arctic species are very slender in form as compared with the tropical blennies, and this fact, caused by a great increase in the number of their vertebræ, has led to the separation of the group into several families. The tropical forms composing the family of *Blenniidæ* have from 28 to 49 vertebræ, while in the arctic genera the numbers range from 75 to 100.

The anacanthine fishes in whole or in part seem to have sprung from a blennioid stock. Of these the most specialized group is that of the flounders (*Pleuronectidæ*), already described. The wide distribution of this family, its members being found on the sandy shores of the zones, renders it especially important in the present discussion. The other anacanthine families are chiefly confined to the cold waters or to the depth of the seas. In the cod family (*Gadidæ*) the number of vertebræ is usually about 50, and in their deep-sea allies, the grenadiers or rat-tails, the numbers range from 65 to 80.

Of the families confined strictly to the fresh waters, the great majority are among the soft-rayed or physostomous fishes, the allies of the salmon, pike, carp, and cat-fish. In all of these the vertebræ are numerous. A few fresh-water families have their affinities entirely with the more specialized forms of the tropical seas. Of these the *Centrarchidæ* (comprising the American fresh-water sun-fish and black bass) have on the average about 30 vertebræ, the pirate perch 29, and the perch family, perch and darters, etc., 35 to 45, while the *Serranidæ* or sea bass, the nearest marine relatives of all these, have constantly 24. The marine family of demoiselles (*Pomacentridæ*) have 26 vertebræ, while 30 to 40 vertebræ usually exist in their fresh-water analogues (or possibly descendants), the *Cichlidæ*, of the rivers of South America and Africa. The sticklebacks, a family of spiny fishes, confined to the rivers and seas of the north, have from 31 vertebræ to 41.

It is apparently true that among the free-swimming, or migratory pelagic fishes, the number of vertebræ is greater than among their relatives of local habits. This fact is most evident among the Scombriform fishes, the allies of the mackerel and tunny. All of these belong properly to the warm seas, and the reduction of the vertebræ in certain forms has no evident relation to the temperature, though it seems to be related in some degree to the habits of the species. Perhaps the retention of many segments is connected with that strength and swiftness in the water for which the mackerels are pre-eminent.

The variations in the number of vertebræ in this group led Dr. Günther, nearly thirty years ago, to divide it into two families, the *Carangidæ* and *Scombridæ*. The *Carangidæ* are tropical shore fishes, local or migratory to a slight degree. All these have from 24 to 26 vertebræ. In their pelagic relatives, the dolphins, there are from 30 to 33; in the opahs, 45; in the brama, 42; while the great mackerel family, all of whose members are more or less pelagic, have from 31 to 50. Other mackerel-like fishes are the cutlass fishes, which approach the eels in form and in the reduction of the fins. In these the vertebræ are correspondingly numerous, the numbers ranging from 100 to 160. In apparent contradistinction to this rule, however, the pelagic family of sword-fishes, remotely allied to the mackerels, and with even greater powers of swimming, has the vertebræ in normal number, the common sword-fish having but 24.

The eels constitute a peculiar group of uncertain but probably soft-rayed ancestry, in which everything else has been subordinated to muscularity and flexibility of body. The fins, girdles, gill arches, scales, and membrane bones are all imperfectly developed or wanting. The eel is perhaps as far from the primitive stock as the most highly ichthyized fishes, but its progress has been of another character. The eel would be regarded in the ordinary sense as a degenerate type, for its bony structure is greatly simplified as compared with its ancestral forms, but in its eel-like qualities it is, however, greatly specialized. All the eels have vertebræ in great numbers. As the great majority of the species are tropical, and as the vertebræ in very few of the deep-sea forms have been counted, no conclusions can be drawn as to the relation of their vertebræ to the temperature.

It is evident that the two families most decidedly tropical in their distribution, the morays and the snake-eels, have diverged farthest from the primitive stock. They are most "degenerate," as shown by the reduction of their skeleton. At the same time they are also most decidedly "eel-like," and in some respects, as in coloration, dentition, muscular development, most highly specialized. It is evident that the presence of numerous vertebral joints is essential to the suppleness of body which is the eel's chief source of power. So far as known, the numbers of vertebræ in eels range from 115 to 160, some of the deep-sea eels having probably higher numbers, if we can draw inferences from their slender or whip-like forms; but this character may be elusive.

The sharks show likewise a very large number of vertebræ, 130 to 150 in the species in which they have been counted. In these fishes no comparative study of the vertebræ has been made. The group is a very ancient one in geological time, and in the comparatively few remaining members of the group, the vertebræ, in fact the entire skeleton, is in a very primitive condition. The sharks are free-swimming fishes, and with them as with the eels, flexibility of body is essential to the life they lead.

In some families the number of rays in the dorsal and anal fins is dependent on the number of vertebræ. It is therefore subject to the same fluctuations. This relation is not strictly proportionate, for often a variable number of rays with their interspinal processes will be interposed between a pair of vertebræ. The myotomes or muscular bands on the sides are usually coincident with the number of vertebræ. As, however, these and other characters are dependent on differences in vertebral segmentation, they bear the same relations to temperature that the vertebræ themselves sustain.

From the foregoing examples we may conclude that, other things being equal, the numbers of vertebræ are lowest in the shore-fishes of the tropics, and especially in those of local habits, living about rocks and coral reefs. The cause of this is to be found in the fact that in these localities the influences of natural selection are most active. The production of vertebræ may be regarded as a phase in the process of specialization which has brought about the typical spiny-rayed fish.

These influences are most active in the warm, clear waters of tropical shores, because these regions offer conditions most favorable to fish-life, and to the life of the greatest variety of fishes. No fish is excluded from competition. There is the greatest variety of competitors, the greatest variety of fish-food, and the greatest variety of conditions to which adaptation is possible. The number of species visiting any single area is vastly greater in the tropics than in cold regions. A single drawing of the net on the shores of Cuba will obtain more different kinds of fish than can be found on the coasts of Maine in a year. Cold, monotony, darkness, isolation, foul water,—all these are characters opposed to the formation of variety in fish-life. The absence of these is a chief feature of life in the tropical waters.

The life of the tropics, so far as the fishes are concerned, offers analogies to the life of cities, viewed from the standpoint of human development. In the same way, the other regions under consideration are, if we may so speak, a sort of ichthyological backwoods. In the cities, in general, the conditions of individual existence are most easy, but the competition is most severe. The struggle for existence is not a struggle with the forces and conditions of nature. It is not a struggle with wild beasts, unbroken forests, or a stubborn soil, but a competition between man and man for the opportunity of living.

It is in the cities where the influences which tend to the modernization and concentration of the characters of the species, the intensification of human powers and their adaptation to the various special conditions, go on most rapidly. That this intensification is not necessarily progress, either physically or morally, is aside from our present purpose.

It is in the cities where those characters and qualities not directly useful in the struggle for existence are first lost or atrophied. Conversely it is in the "backwoods," the region most distinct from human conflicts, where primitive customs, antiquated peculiarities, and useless traits are longest and most persistently retained. The life of the backwoods will be not less active and vigorous, but it will lack specialization.

It is not well to push this analogy too far, but we may perhaps find in it a suggestion as to the development of the eels. In every city there is a class which partakes in no degree of the general line of development. Its members are specialized in a wholly different way, thereby taking to themselves a field which the others have abandoned, and making up in low cunning what they lack in strength and intelligence. Thus among the fishes we have in the regions of closest competition a degenerate and non-ichthyized form, lurking in holes among rocks and creeping in the sand, thieves and scavengers among fishes. The eels fill a place which would otherwise be left unfilled. In their way, they are perfectly adapted to the lives they lead. A multiplicity of vertebral joints is useless to the typical fish, but to the eel strength and suppleness are everything, and no armature of fin or scale or bone so desirable as its power of escaping through the smallest opening.

It may be too that, as rovers in the open sea, the strong swift members of the mackerel family find a positive advantage in the possession of many vertebræ, and that to some adaptation to their mode of life we must attribute their lack of ichthyization of the skeleton. But this is wholly hypothetical, and we may leave the subject with the general conclusion that with the typical fish advance in structure has specialized the vertebræ, increased their size and the complexity of their appendages, while decreasing their numbers; and that, with some exceptions and modifications, this reduction is characteristic of fishes in the tropics, and that it is so because in the tropics the processes of evolution are most active, so far as the fishes are concerned.

## LETTERS TO THE EDITOR.

**** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

*On request in advance, one hundred copies of the number containing his communication will be furnished free to any correspondent.*

*The editor will be glad to publish any queries consonant with the character of the journal.*

### Fair-Weather Echoes.

MY dog, a deep-voiced Newfoundlander, has one plague in life — an echo. It comes from a cottage some three hundred yards off, and there that "other dog" will always have the last word. This is exasperating, and "Graph" —he is named after another sound-producer, the graphophone — gives vent to his anger in a series of short, sharp, threatening yelps, which are of course more distinctly reproduced than the long bow-wows and howls. Last night Graph was very noisy, but the echo was silent. I tried to rouse it, and excited Graph to do his utmost, but with no effect. A moderate, even-down rain was falling, and the fair-weather echo would not venture out. There is, of course, a reason for this, but I had never noticed the fact before. Is the explanation that the lines of rain cut through the aerial sound-waves and stop them? Are echoes among the hills interfered with by rain?

When the shower was over I tested the echo again, and there it was, a little fainter than usual, but persistent as ever.

A. M. B.

Colonial Beach, Va., Aug. 13.

### Number of Words in an Ordinary Vocabulary.

IN examining the vocabularies of children, my interest in the size and nature of the vocabulary of an ordinary person, previously aroused by the varying statements and estimates I have seen, was excited sufficiently to induce me to spend a portion of my vacation in making some investigations, the results of which may be of interest to the readers of *Science*.

I first turned to Webster's Unabridged Dictionary (edition of 1870), and counted the words on every twenty-fifth page, and found the percentage of them whose meaning was known to me. Then by calculation I found that if the same percentage holds for the other pages I must know the meaning of nearly seventy thousand of the words given in that edition of the dictionary. Since in the dictionary a word as a transitive verb, as an intransitive verb, as a noun, as an adjective, as an adverb, is separately defined, as well as when used with a prefix, a suffix, or in a compound; and since the irregular plurals, adjectives irregularly compared, and the parts of irregular verbs are also given, this number is perhaps twice that of the really different words. The meaning of some of these words was readily divined from their form, although they had never been seen. On the other hand, one word not unfrequently has a dozen different shades of meaning, several of which often require as different and definite associations as entirely distinct words. Hence the effort required to learn all of these words, with their different shades of meaning, but similar form, is probably as great as it would be to have seventy thousand different words, each having but one meaning. I did not understand the meaning of all of the words well enough to define and use them with accuracy, but merely well enough to grasp their meaning in any sentences in which they might be used, and I probably have never actually used a fourth of them. But, besides the words in the dictionary and some new words given in later editions, and a number of words and phrases from other languages in common use, there are probably several thousand proper names, such as are found in history, geography, fiction, and among acquaintances, each with its distinct associations, familiar to every intelligent person. These words will more than make up for any error in counting that I could have made.

Professor E. S. Holden (Trans. Philol. Soc., 1877), found his own vocabulary to be between thirty-three and thirty-four thousand words, and estimated that of an ordinarily intelligent person at twenty-five thousand. I do not know what he called a word, nor whether he counted as known words that he could not or did not use. He estimates that the vocabulary of technical terms possessed by a specialist may reach ten thousand or more. In "Gray's Structural Botany" there is a glossary of between two and three thousand technical terms, the vast number used in cryptogamic botany not being included in the list, and of course none of the special names of plants, so it is not improbable that a well-read botanist may have a technical vocabulary of ten thousand words, and a zoologist a greater number.

The words in common use by the ordinary individual has been estimated at from one to three thousand, and it is claimed that when one has learned the meaning of that many words he can carry on any ordinary conversation or understand common, gen-