DISTRIBUTION OF HIMALAYAN FISHES AND ITS BEARING ON CERTAIN PALAEOGEOGRAPHICAL PROBLEMS.

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The physical and biological factors that govern the life of a torrential fauna[1] are of a very special nature and tend to restrict the distribution of hill-stream animals. Of the various physical factors, two are of special significance, the rapidity of the current and the consequent high percentage of dissolved air in mountain brooks. In response to the former, the organisms have developed various types of adhesive devices to prevent being washed away by the strong currents and spend most of their life clinging to rocks and boulders, while the greatly flattened or torpedo-shaped body presents a stream-lined form to the rushing current. As an adaptation to the high percentage of oxygen in these waters, the respiratory organs are reduced, for in such habitats even a comparatively much smaller area is sufficient to absorb enough oxygen for the requirements of an organism. Hill-stream animals are, as a rule, not suited for existence in muddy, sluggish water, and under such conditions usually die through asphyxiation within a very short period. As an example of biological factors, attention may be directed to the fact that the majority of the hill-stream fishes feed by scraping off algal slime and insect larvae that encrust rocks and stones, and consequently their mouths and jaws are specially modified for this purpose. It is obvious that the same method of feeding cannot be employed on a muddy substratum.

The distribution of the highly specialised hill-stream fishes, therefore, cannot be affected by the ordinary methods of dispersal along water channels, because the nature of the substratum[2] and the rapidity of the current are very potent factors for the existence of these animals. Their distribution along a mountain range has to be explained in terms of river-captures, longitudinal river valleys or tilting of mountain blocks so that the courses of the streams may alter without impairing their torrential nature. The distribution of the southern Himalayan fishes shows that all the three processes have been responsible in varying degrees for the dispersal of the fish fauna in this region, and that the Himalayan uplifting movement, though it may have been fairly uniform in the beginning over large areas, certainly became localised towards the end. Through the influence of these unequal orogenic movements, extending from the middle Eocene to almost within, geologically speaking, recent times, the Himalayas became hydrographically divided into a number of units which can be roughly demarcated with the help of their fish faunas. It is the object of this article to elucidate the probable

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[1] Hora, S. L.—Ecology, Bionomics and Evolution of the Torrential Fauna, with special reference to the organs of attachment. *Phil. Trans. Roy. Soc. London*, B, CCXVIII, pp. 171-282 (1930).

[2] Hora, S. L.—Nature of Substratum as an important factor in the ecology of Torrential Fauna. *Proc. Nat. Inst. Sci. India*, II, pp. 45-47 (1936).

boundaries of these hydrographical divisions of the Himalayas. Evidence is also adduced from the nature of the fish faunas of the north and south faces of the Himalayas to discuss whether the present-day drainage of the Himalayas is evolved from an ordinary " consequent drainage ", *i.e.*, the rivers flowed north or south of the crest, or is the result of an " antecedent drainage " Observations are also made regarding the existence of the so-called " Indobrahm " or the " Siwalik River " of the Tertiary period.

Distribution of Fishes along the southern face of the Himalayas.

Ecologically, the Himalayan fishes can be divided into several categories and in discussing their geographical distribution it is well to bear in mind their respective associations. For instance, several species of *Barbus* Cuvier and *Labeo* Cuvier occur all along the Himalayas, but essentially they are forms of the plains which live in pools or deeper portions of the streams of the Himalayan foot-hills ; some of them maintain themselves in swift currents through sheer muscular efforts. *Oreinus* McClelland, on the other hand, represents the Central Asiatic element on the southern face of the Himalayas ; it spreads from Afghanistan, along the whole of the Himalayas and the contiguous ranges of hills, to south-eastern China. So far as is known, the fishes of this genus appear to be strictly residents of rivers in hilly regions, neither descending far into the plains nor occurring on level plateaux on the summits of mountains. Unlike the other Schizothoracinae, their mouths are provided with an adhesive device which enables them to resist being washed away in mountain torrents. *Oreinus* is a trout-like muscular fish and seems to have evolved from stocks of *Schizothorax* Heckel that may have been washed down from the Trans-Himalayan sections of some of our modern rivers.

A group of genera,[1] comprising *Crossochilus* van Hass., *Semiplotus* Bleeker, *Chaca* Gray, *Sisor* Hamilton, *Leiocassis* Bleeker, *Gagata* Bleeker, *Nangra* Day, *Bagarius* Bleeker, etc., is found in the streams of the foot-hills in comparatively deeper and less rapid-flowing waters ; while Loaches or Loach-like cat-fishes, such as *Nemachilus* van Hass., *Lepidocephalichthys* Bleeker, *Acanthophthalmus* van Hass., *Somileptes* Swainson, *Acanthopsis* van Hass., *Olyra* McClelland, *Amblyceps* Blyth, *Erethistes* Müll. and Trosch., *Parasilurus* Bleeker, etc., live among pebbles and stones at the bottom and escape the effect of the rushing current. Though *Garra* Hamilton and *Glyptothorax* Blyth are provided with adhesive devices they are found both in torrential streams and in streams with moderate currents. These are essentially rapid-water forms, but have taken secondarily to slow waters. The typical torrential genera are *Pseudecheneis* Blyth, *Exostoma* Blyth, *Euchiloglanis* Regan, *Balitora* Gray and certain species of *Psilorhynchus* McClelland ; these are res-

[1] Attention may also be directed to the amphibious, marsh-loving fishes of the genus *Opiicephalus* which are sometimes found at the sides of mountain streams in burrows and are not affected by the strength of the current. These are found throughout the plains of south-eastern Asia and are capable of wriggling about on wet ground.

tricted in their distribution to very fast flowing waters, and are accordingly the most highly adapted forms for life in mountain brooks.

Before discussing the distribution of the genera enumerated above, it seems worth while to form some conception of the age and geographical divisions of the Himalayas. According to Burrard, Hayden and Heron (p. 86)[1],

" Though the whole length of the great Himālaya range belongs to one geological age, yet the Punjab Himālaya are supposed to have arisen at a somewhat later date than the Nepāl Himālaya. The presence at elevations of 16,000 feet in the Punjab Himālaya of nummulites indicates that this portion of the range did not emerge from the sea till comparatively recently."

It is further stated that

" The rocks of the Siwalik range are stratified and date from the later half of the Tertiary period ; those of the outer Himālaya are stratified also but are very much older."

For descriptive purposes the total length of the Himalayas from Namcha Barwa in the east to Nanga Parbat on the west, about 1,500 miles, is divided into four sections by three meridional lines, (i) The Tista, (ii) The Kali and (iii) The Sutlej. The easternmost section, about 450 miles, is known as the Assam Himalayas, the next section of about 500 miles is the Nepal Himalayas, then a length of about 200 miles is the Kumaon Himalayas and the last about 350 miles form the Punjab Himalayas.

" Whilst in all the four parts the great range rises like a wall and the outer ranges tend to run parallel to it, no one portion of the Himālaya resembles another."

" In Nepāl we find numerous rivers cutting across the Great Himālaya range ; in the Punjab between the Sutlej and the Indus we do not find one. In Nepal the great peaks stand in clusters and rows ; the great peak of the Punjab stands in solitude."

In considering the distribution of fishes along the south face of the Himalayas, there is one fact which appears most striking at the very outset, *i.e.*, the great variety of forms towards the east as compared with the case of the west. For instance, in the Brahmaputra and the Tista drainage systems all the genera of fishes enumerated above are found ; while towards the west in the Gangetic drainage system we only find *Chaca*, *Amblyceps*, *Bagarius*, *Glyptothorax*, *Erethistes*, *Gagata*, *Nangra*, *Lepidocephalichthys*, *Nemachilus*, *Garra* and *Semiplotus*. Not one of these genera represents a highly specialised torrential form, and, with the exception of *Gagata*, *Nangra* and *Semiplotus*, all are widely distributed in the Oriental Region ; the range of *Nemachilus*, *Garra* and *Glyptothorax* extends for a considerable distance towards the west. There is one genus of large Catfishes—*Sisor* Hamilton—which was recorded by Day from both the Indus and the Ganges systems ; but it was found by Shaw and Shebbeare and Mukerji to occur also in the Tista river. In the Punjab Himalayas or the Indus drainage system *Chaca*, *Erethistes* and *Semiplotus* are absent. Unfortunately no systematic account of the Himalayan fishes has so far been published, and in the case of old records precise localities are not mentioned. In the case of *Semiplotus*, however, it may be noted that Day gave its distribution as " Assam, and Chittagong Hill ranges, as well as Burma ", but recently

[1] Burrard, S. G. and Hayden, H. H.—*A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet.* 2nd Edition, revised by Burrard, S. G. and Heron, A. M. (Delhi : 1933).

I[1] recorded *S. semiplotus* (McClelland) from the portion of the Nepal Himalayas drained by the Gandak. Though our present-day knowledge of the distribution of the Himalayan fishes is very imperfect, it is doubtful whether the special forms of the Assam Himalayas, such as *Balitora, Psilorhynchus, Parasilurus, Olyra, Pseudecheneis*, etc., will ever be found in the western Himalayas. These very genera or some other closely allied forms are found in Burma, Southern China, Siam, the Malay Peninsula and the Archipelago and Indo-China on the one hand and in the hills of Peninsular India on the other. It seems remarkable that the distribution of these eastern forms, instead of being continued along the Himalayas, is deflected from the limits of the Tista drainage towards the south. This most striking feature in the distribution of Indian fishes is explained later (*vide infra*, p. 255).

The records of distribution of the Himalayan fishes, as given above, support the hypothesis that I[2] have suggested elsewhere regarding the eastern origin of the freshwater fish fauna of India. The above series of genera represents various phases of migration of the fauna. For instance, in the case of such widely distributed genera as *Barbus, Labeo, Garra, Nemachilus, Lepidocephalichthys, Bagarius, Amblyceps*, etc., one has to imagine a large, deep river in low hills fed by small, broad, rocky tributaries. The wide distribution of these genera along the entire length of the Himalayan foot-hills shows further that such a river must have had a longitudinal course, like that of the Trans-Himalayan sections of the Brahmaputra and the Indus. It was, no doubt, during this type of drainage of the Himalayas that the large river fishes of India, such as *Catla* (represented in Siam and Indo-China by *Carpiocatla* Boulenger), *Cirrhina*, large-scaled Barbels, *Wallago* Bleeker, *Silonia* Swainson (replaced in Siam and Indo-China by *Pangasianodon* Chevey), *Pangasius pangasius* (Ham.), etc., could spread almost all over India. The presence in the Ganges, Brahmaputra and Indus of identical species of freshwater dolphins and turtles also shows the course and nature of this mighty river. Thus the distribution of the freshwater fish fauna of northern India lends a strong support to the existence of a river of the type of the Indobrahm, envisaged by Pascoe[3] and Pilgrim[4]. From the geological evidence it is concluded by these authors that such a river existed even in the Eocene period. Its lower course is evident from the distribution of the boulder conglomerates, but the position of its headwaters is a matter of mere conjecture. It is stated that the headwaters of the Indobrahm consisted of the Assam portion of the present-day Brahmaputra. Dr. C. S. Fox of the Geological Survey of India has pointed out to me in a note that this cannot be the case as

" A marine gulf in Burma and Upper Assam in Cretaceous times became an estuary in the Eocene and the mouth of a very important river in the Miocene. I do not see how

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[1] Hora, S. L.—Notes on Fishes in the Indian Museum, XXIX. On a Collection of Fish from Nepal. *Rec. Ind. Mus.*, XXIX, pp. 45, 46 (1937).

[2] Hora, S. L.—Geographical Distribution of Indian Freshwater Fishes and its bearing on the probable land connections between India and the adjacent countries. *Curr. Sci.*, V, pp. 351-356 (1937).

[3] Pascoe, E. H.—Early History of the Indus, Brahmaputra and Ganges. *Quart. Journ. Geol. Soc.*, LXXV, p. 136 (1919).

[4] Pilgrim, G. E.—Suggestions Concerning the History of the Drainage of Northern India. *Journ. As. Soc. Bengal* (N. S.), XV, p. 81 (1919).

the debouchure of a river into a delta can become the source of a river that is to go to sea all the way round the Himalayan foothills to the Indus."

In the same note he stated that

"It is probable that as the old geosyncline of the Himalayan belt was folded up into a mountain chain a depression was established parallel to it to the south. In the swampy country the rivers from the rising hills discharged, and their silt was spread out laterally into great alluvial fans. It is these Siwalik deposits of freshwater fluviatile deposition that have been joined up lengthways, along the axis of the depression, and thus have supplied material for the belief in a Siwalik river."

This view is, however, disputed by Wadia[1] who has drawn attention to the remarkable homogeneity and uniformity of the Siwalik deposits all along this strike, from Assam to the Punjab. This strike continuity is inconsistent with the fan theory of deposition at the mouths of isolated transverse streams and is best explained by deposition in a continuous longitudinal basin of a wide east-west flowing river.

Without going into the geological merits of the case, it seems clear that the distribution of freshwater fishes, as indicated above, postulates the existence of a mighty river of the nature of the Indobrahm.[2] This river at an early stage of its existence certainly did not have its headwaters in the Assam portion of the present-day Brahmaputra, but it must have crossed the broad isthmus that joined India with the main Asiatic continent and had its headwaters further east. The distribution of the large freshwater river fishes of the Oriental Region (*vide supra*, p. 254) can only be explained on this assumption. Even the occurrence of precisely the same river fishes, especially of the giant forms as *Catla catla* (Ham.), *Labeo rohita* (Ham.), *Cirrhina mrigala* (Ham.), *Wallago attu* (Bloch), *Pangasias pangasias* (Ham.), *Silonia silondia* (Ham.), and others in Burma, Assam, Bengal, the United Provinces, the Central Provinces, Orissa and the Punjab postulates the existence of a large, longitudinal river and its subsequent divisions into several independent watersheds. As the Himalayas rose to a great height in the region of this isthmus (mostly the western part of the Assam Himalayas and eastern part of the Nepal Himalayas) all the evidence concerning the north-eastward extension of the Indobrahm seems to have been obliterated. The uplift movement was probably most active in this region as we find practically all the highest peaks of the Himalayas clustered round this area. This differential movement, which probably occurred late in the Miocene period, must have obliterated all traces of the eastward extension of the Indobrahm and also acted as a barrier between the eastern and the western Himalayan fishes. The new stocks of specialised hill-stream fishes from the east, not finding means to cross this barrier, were deflected towards south-west along the Satpura Trend which probably at this period stretched across India as a pronounced

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[1] Wadia, D. N.—The Tertiary Geosyncline of North-West Punjab and the History of Quaternary Earth-movements and Drainage of the Gangetic Trough. *Q. J. Geol. Min. Met. Soc. Indiz*, IV, pp. 69-96 (1932).

[2] Evidence of the existence of the Indobrahm is also furnished by "the tendency of the tributaries of the supposed Indobrahm to flow in a direction opposite to that of the modern trunk river. If but one feeder has been observed to take a course contrary to that of the main stream, it might have been attributed to some local accident of topography, but when all the principal affluents of a long section of the river do so, it is indicated that the Indobrahm flowed from east to west, when the tributaries were developed, and that its direction of flow has been reversed." (Burrard, Hayden and Heron, *op. cit.*, p. 349.)

range from Gujarat to the Assam Himalayas. From Gujarat the hill-stream fauna migrated towards the south along the Western Ghats and spread to the hills of the Peninsula in the extreme south. It may here be noted that the Indobrahm fauna of moderate, deep currents does not extend to the south below the Kistna river, while the torrential fauna of the Eastern Himalayas is represented in the hills of the extreme south of the Peninsula by forms such as *Silurus* Linn., *Bhavania* Hora, *Parapsilorhynchus* Hora, *Thynnichthys* Bleeker, etc.; it is not found in Ceylon, for the island had by then become separated from the mainland. Further, it has no representative in Africa, because the main land bridge between Peninsular India and Africa had already disappeared during the Eocene period, though a mass of land in the region of the Gulf of Oman probably existed till Pliocene or possibly even Pleistocene times.[1] This course of events, in my opinion, explains the anomalous distribution of the various hill-stream fishes of India, and suggests a reason for the closer similarity of the South Indian fish fauna with that of the Malay Peninsula and the Archipelago.

To the west of this supposed barrier in the Eastern Himalayas the hill-stream fauna is composed of ordinary rapid water fishes; most of the genera are more or less uniformly distributed all along the range. In the Nepal Himalayas, however, the eastern element, *Semiplotus*, *Chaca* and *Erethistes*, is more pronounced. The last two genera extend up the Ganges system and are absent from the Punjab Himalayas. The Punjab Himalayas, being furthest from the source of distribution, has the least number of hill-stream forms in its fauna. It may, therefore, be presumed that at the end of the Kumaon Himalayas or somewhere in that region there is probably another barrier, which isolated the fauna of the Punjab at a fairly early age. This conclusion is justified by the detailed studies recently carried out by Mukerji[2] and Hora[3] on the specific position of some of the Himalayan fishes. The isolation of the Punjab Himalayan forms may have resulted through the differential earth-movements which elevated the Potwar basin into a plateau and led to further dismemberment of the Indobrahm into the Indus and the Ganges systems of the present-day drainage of the Himalayas. In any case, this barrier must have been formed at a later date and is not contemporaneous with the Eastern Himalayan barrier. This presumption is based on the fact that after the formation of the Eastern Himalayan barrier there was for some time no river of the nature of the Ganges flowing into the Bay of Bengal to divide the Peninsula from the Extra-Peninsula: such a river, if it had existed, would in itself have acted as a barrier and have inhibited the dispersal of Himalayan fishes to the hills of the Peninsula. It is thus seen that the Indobrahm must have continued to flow towards the Arabian Sea even after the severence of its

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[1] Wiseman, J. D. H. and Sewell, R. B. S.—The floor of the Arabian Sea. *Geol. Mag.*, LXXIV, pp. 219-230 (1937).

[2] Mukerji, D. D.—Report on Burmese Fishes collected by Lt.-Col. R. W. Burton from the tributary streams of the Mali Hka river of the Myitkyina District (Upper Burma). *Journ. Bombay Nat. Hist. Soc.*, XXXVII, pp. 49-59 (1934).

[3] Hora, S. L.—On a further Collection of Fish from the Naga Hills. *Rec. Ind. Mus.*, XXXVIII, pp. 320-324 (1936).

connection with the Far East ; its dismemberment seems to have occurred in several stages. After the formation of the Eastern Himalayan barrier its headwaters may have been in the Nepal Himalayas. A later upheaval probably divided it into a westerly flowing Indus and an easterly flowing Ganges. The formation of this drainage pattern has a counterpart on the northern face of the Himalayas also, namely, the reversal of the direction of flow of the Tsangpo towards the east and the westerly flowing Indus.

From the distribution of the fish fauna along the southern face of the Himalayas it is thus possible to recognise three well marked divisions—the Eastern Section up to and including the drainage basin of the Tista river, the Middle Section up to the Sutlej river and then the Western Section comprising the entire drainage basin of the Indus. The precise boundaries of these sections can only be demarcated when our knowledge of the various Himalayan species and their races becomes more exact. It may be indicated that the Jumna river was a tributary of the Sutlej not very long ago, though it now joins the Ganges. The oscillation of the Jumna makes it still more difficult to define the various sections without a proper survey of the fish fauna of the Himalayas.

HIMALAYAN FISHES AND THEIR BEARING ON THE EVOLUTION OF THE PRESENT-DAY DRAINAGE SYSTEM OF THE HIMALAYAS.

With the exception of *Oreinus* and *Nemachilus*, none of the genera enumerated above are found on the northern face of the Himalayas, the fish fauna of which comprises the Schizothoracinae, *Glyptosternum* McClelland and *Nemachilus*. In another place I[1] have shown that the Nemachili of the northern and the southern faces of the Himalayas are very distinct from each other and that *Glyptosternum* is very different from the other Glyptosternoid fishes found in Siam, S. China, Burma and the Eastern Himalayas. *Oreinus* is a mountain form of *Schizothorax* Heckel and is only found along the slopes of the Central Asiatic plateau, but not on the tableland. In fact, it may definitely be stated that there is no similarity between the fish faunas of the northern and the southern faces of the Himalayas. To account for this I have suggested that the two faunas were probably evolved from the same stock at different geological ages and owing to the barrier provided by the rising Himalayas had little chance to intermingle. The deep gorges and rapids in the course of certain Himalayan rivers with trans-Himalayan courses still isolate the two fish faunas from each other.

With regard to the evolution of the present-day Himalayan drainage pattern two alternative theories have been advanced.

" One of the theories postulates that at an early age the Himalaya had ordinary consequent drainage, the rivers flowing north and south from the crest. This simple drainage pattern is considered to have been modified to its present form by some of the south-flowing rivers cutting back through the range and capturing rivers on the Tibetan side. The much greater precipitation on the south side of the range and the much steeper fall and therefore greater erosive power are put forward as possible reasons for the unusual behaviour of the south-flowing rivers. The alternative theory postulates that the Arun and similar rivers always had their present courses which, when they were inaugurated, were the easiest routes down an irregular surface sloping towards the

[1] Hora, S. L.—Comparison of the Fish-Fauna of the northern and the southern faces of the great Himalayan range. *Rec. Ind. Mus.*, XXXIX, pp. 241-250 (1937).

Gangetic plain. Subsequently the Himalayan range is considered to have risen up across the rivers, but so slowly that by vigorous erosion they were able to keep open their original channels."[1]

The distinctness of the northern and the southern fish faunas of the Himalayas definitely favours the former view. If the rise of the Himalayas had been so slow as to enable the rivers to keep open their channels by vigorous erosion there should have been little or no difference in the fish faunas of the cis- and trans-Himalayan portions of such rivers as the Brahmaputra, the Arun, the Sutlej, the Indus, etc. On the other hand, there is every reason to believe that the rise of the Himalayas was in sharp orogenic movements so that the fishes of the southern face of the range were unable to adapt themselves to very turbulent waters and have, even to this day, remained confined to low valleys and are rarely found above an elevation of four to five thousand feet. In this connection it may also be remembered that the so-called Indian monsoon conditions—south-west for four months and north-east for three or four months—had begun before the Himalayas started to rise, as in the late Cretaceous period open seas of great extent existed to the south of India and some land had been formed to the north. The rise of the Himalayas had a great influence on the distribution of rainfall, for most of the moisture is now precipitated on its southern face; and there is practically no rainfall on the northern face of the Himalayas. Consequently, the rivers along the southern face are very turbulent while those on the northern face are placid, broad-valleyed and deep. Very different sets of ecological conditions were thus produced on the northern and southern faces of the Himalayas and these became accentuated as the mountains rose higher and higher.

When the south-flowing rivers, through erosion captured the rivers on the Tibetan side it was natural that some of the fishes on the Tibetan side should have been washed down on the southern side, but they had to pass through such precipitous channels before reaching congenial conditions that with the exception of one genus of the Schizothoracinae—*Oreinus*, a specialised member of the subfamily fully adapted for life in rapid, mountain streams—no other member of the Central Asiatic fauna has been able to colonise the southern slopes of the Himalayas.

The migration of torrential fishes along the southern face of the Himalayas and from the Eastern Himalayas to the hills of the Peninsula shows that the process of river-capture was a fairly common phenomenon in this territory and also in the region of the contiguous hill-ranges to the east. The distribution of specialised hill-stream fishes strongly suggests that in south-eastern Asia, as a rule, the rivers on the west beheaded the rivers on the east[2] and thus effected the transference of the fish fauna from the east to the west.

SUMMARY.

The physical and biological factors that govern the life of a torrential fauna are examined and it is indicated that the distribution of highly

[1] Wager, L. R.—The Arun River Drainage Pattern and the rise of the Himalayas. *Geog. Journ.*, LXXXIX, pp. 239-250 (1937).

[2] Gregory, J. W.—The Evolution of the River System of South-Eastern Asia. *Scottish Geog. Mag.*, XLI, pp. 129-141 (1925).

specialised hill-stream fishes cannot be effected by the ordinary methods of dispersal; it has to be explained in terms of longitudinal valleys, river-captures and tilting of mountain blocks.

The distribution of the fish-genera along the southern face of the Himalayas is discussed in terms of the ecological associations of the different types, and it is indicated that at a very early period of the rise of the Himalayas a mighty longitudinal river must have existed along its base. This river probably corresponded with the 'Indobrahm' of Pascoe and Pilgrim, but the distribution of fishes shows that it must have extended towards the Far East. From the distribution of various fishes the probable phases of dismemberment of this river are indicated, and it is explained how the Himalayas became divided hydrographically into three main divisions—the Brahmaputra, the Ganges and the Indus drainage systems.

The almost total dissimilarity between the northern and the southern Himalayan fishes is indicated, and it is concluded therefrom that the present-day drainage pattern of the Himalayas cannot have resulted from an antecedent drainage, according to which the Himalayan range is considered to have risen up across the rivers which kept their original channels open by vigorous erosion, but is the result of consequent drainage, of which the southern rivers captured the rivers of the north secondarily.