Comparative Studies of the Scales in Japanese Freshwater Fishes, with Special Reference to Phylogeny and Evolution

Continued from p. 191

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III. General lepidology of freshwater fishes

(1) Kinds of Scales

Among the freshwater fishes treated in this paper, Mugilidae, Centrarchidae, Kuhlidae, Sparidae and Theraponidae are perfect possessors of ctenoid scales, while some fishes of Anabatidae and Gobiidae possess both cycloid and ctenoid scales, and Serranidae has two groups, one with cycloid scales and the other with ctenoid scales. Most fishes of Gobiidae are possessors of ctenoid scales, but, as above mentioned, they retain cycloid scales in some parts of the body, and are mixed with possessors of cycloid scales only, and with those which have finally degenerated to be entirely scaleless. The other 16 families are all possessors of cycloid scales only. (Fig. 1.)

(2) Contours of Scales

Contours of scales are extremely complicated and various in shape. i. e., spherical, elliptical, oval, quadrangular, hexagonal, diamond, irregular, etc. It makes outlines of scales different that some have both the basilateral and apicolateral angles, some the same angles very distinct and nearly right-angled, and some these angles projected. Some fishes have the basimedian angles (e. g., Acheilognathinae), and the scales in c. b. s. of *Trypauchen vagina microcephalus* in Gobiidae have no basilateral and apicolateral angles at all, whose outline is diamond, as the basal tip and the apex are projected at the upper and lower basimedian angles.

The from and size of the four areas of scales are entirely different according as in what part of scales the focus is situated. When the

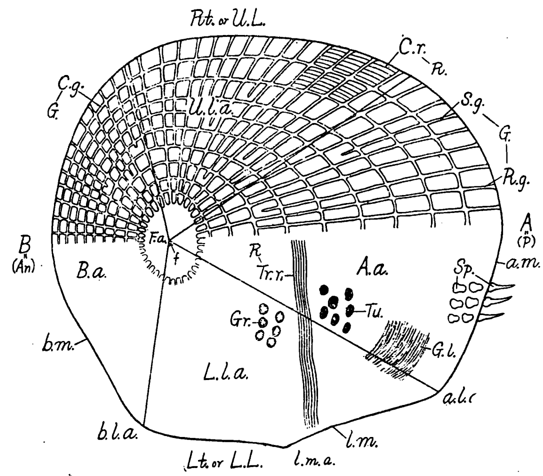
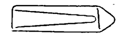


Fig. 1. Important technical terms of scale used in this study. A. a. Apical area; A. Apical; a.l.a. Apicolateral angle; A.m. Apical margin; (An) Anterior; B. Basal; B. a. Basal area; b.l.a. Basilateral angle; b.m. Basal margin; C.g. Circular groove; C.r. Circular ridge; f. Focus; F.a. Forcal area; G. Groove; Lt. or L.L. Left or lower lateral; l.m. lateral margin; l.m.a. Lateromedian angle; (P) Posterior; R. Ridges; Rt. or U.L. Right or upper lateral; S. g. Supplementary groove; Sp. Spines; Tr.r. Transverse ridge; Tu. Tubercle; U.l.a. Upper lateral area.

focus is central, the upper and lower lateral areas are much the same shape, and so are the basal and apical areas, but when the focus is basal, the apical area is enlarged, and when apical, the basal area is enlarged, and most of Gobiidae are extreme examples, having no apical area as the focus joins the apex. It is interesting that fishes of Theraponidae have the basal area of an isoceles triangle, the lateral area of a right-angled triangle, and the apical area of a regular triangle . As to scale margins, there are smooth ones and wavy ones, and this will be shown more concretely as follows:

1) Basilateral angles nearly right-angled.

Brachymystax lenok, Sarcocheilichthys, Coreoleuciscus, Pungtungia, Hemibarbus, Opsariichthys, Macropodus chinensis, Ophicephalidae, Mugilidae.

2) Basilateral angles and apicolateral angles distinct.

Osmerus dentex, Rhodeus sericeus, Ctenopharyngodon idellus, Lateolabrax japonicus, Kuhlia marginata, Sparidae, most part of Gobiidae, *Coreoperca, Siniperca,* Theraponidae.

3) Basal margin waved.

Brachymystax, Thymallidae, *Gambusia affinis, Carassius carassius, Macropodus chinensis,* Ophicephalidae, Mugilidae, *Leiognathus nuchalis, Micropterus salmoides,* Kuhlidae, Serranidae, Theraponidae, Gobiidae.

4) Apical margin waved.

Some Cyprinidae i. e. *Pseudoperilampus, Rhodeus, Hypophthalmichthys molitrix, Biwia zezera, Pungtungia hilgendorfi, Hemibarbus, Belligobio, Leuciscus waleckii, Zacco, Ischikauia steenackeri, Opsariichthys, Hymenophysa curta.*

5) All margins waved.

Phoxinus, Cobitidae, *Periophthalmus cantonensis.*

6) Basal and apical margins waved.

Aphyocypris chinensis, Ctenopharyngodon idellus.

(3) Grooves

Instead of the term 'radii' which has hitherto been used chiefly, the term 'grooves' will be used, because the structure is not always radial, but often runs transverse, and is even circular, making the term radii unreasonable (Kobayasi, 1950). Within the fishes which are made objects of this study, there are many with no grooves at all, some with grooves radiated all around, some with apical grooves but with no other ones, some with basal grooves only, some with more or less lateral grooves (apicolateral grooves) together with apical grooves, some with both apical and basal grooves, some with two different kinds of grooves (one transverse, the other radial), some with a few basal or apical grooves, but with hardly any formation of supplementary grooves, and besides these, variations are to be seen in the condition of each groove. This will be concretely shown as follows:

1) No grooves at all.

Coregonidae, Salmonidae, Plecoglossidae, Osmeridae, Anguillidae, head apex scales of *Channa* and *Macropodus,* breast scales of *Lateolabrax,* young scales of *Hypophthalmichthys.*

2) Grooves radiated all around.

Phoxinus, regenerated scales of *Carassius*, rarely regenerated scales of *Leuciscus waleckii*, Cobitidae, sometimes *Cyprinus*, *Periophthalmus cantonensis* in Gobiidae.

3) Apical grooves only.

All of Acheilognathinae; *Hypophthalmichthys molitrix*; *Zacco*, *Ischikauia steenackeri*, *Opsariichthys uncirostris*, *Hemigrammocypris rasborella*, young scales of *Ctenopharyngodon idellus* in Leuciscinae.

4) Basal grooves only.

Gambusia affinis, s. c. p. scales of *Hemigrammocypris rasborella*, *Mugil cephalus*, *Macropodus chinensis*, *Micropterus salmoides*, *Kuhlia marginata*, *Leiognathus nuchalis*, Epinephelidae, *Lateolabrax japonicus*, Sparidae.

5) More or less lateral grooves besides apical ones.

Sarcocheilichthys, *Hemibarbus*, *Abbottina*, *Pseudogobio esccinus*, rarely *Belligobio*, *Pseudorasbora* in Goboininae; *Tribolodon hakonensis*, rarely *Ischikauia steenackeri* in Leuciscinae.

6) · Both apical and basal grooves.

Coilia; Leuciscus waleckii, *Aphyocypris chinensis*, adult fish of *Ctenopharyngodon idellus* in Leuciscinae; *Carassius carassius*, *Cyprinus carpio*.

7) Two different kinds of grooves.

Harengula zunasi (weakly radiated apical grooves and strongly transverse grooves, *Coilia* (network apical grooves and not reticulated longitudinal basal and lateral grooves).

8) A few basal or apical grooves; few supplementary grooves formed.

Hypophthalmichthys molitrix (apical), s. c. p. scales of *Hemirhamphus*, *Leiognathus nuchalis* (basal), *Micropterus salmoides* (basal), *Ischikauia steenackeri* (apical), *Opsariichthys* (apical), *Hemigrammocypris rasborella* (apical).

9) Many supplementary grooves formed.

Ctenopharyngodon idellus, *Phoxinus*, *Cyprinus carpio*, *Leuciscus* (especially in basal grooves), *Lefua costata*, *Lefua nikkonis*, *Misgurnus*.

10) Both basal and lateral grooves.

Chasmichthys dolichognathus, *Chaenogobius isaza*, *Chaenogobius annularis urotaenia* in Gobiidae; *Coreoleuciscus splendidus*.

11) Grooves remarkably zigzag.

Some Acheilognathinae i. e. *Acheilognathus moriokae*, *A*, *cyanostigma*, *A. intermedia*, *A. lanceolata*, *Paracheilognathus rhombea*, *Acanthorhodeus asmusii*, *A. chankalensis*, *Pseudoperilampus typus*.

12) Grooves straight.

Therapon oxyrhynchus, *T. jarba*, *Leiognathus nuchalis*, *Sparus swinhonis*, *Micropterus salmoides*, *Macropodus chinensis*.

13) Grooves remarkably thickend in the middle part.

Some Acheilognathinae i. e. *Acheilognathus tabira*, *Acanthorhodeus guichenoti*, *Rhodeus ocellatus*, *Acanthorhodeus gracilis*, *Pseudoperilampus typus*, *Rhodeus sericeus*.

14) Grooves remarkably waved.

Some Acheilognathinae i. e. *Paracheilognathus rhombea, P. tabira P. coreanus, Acheilognathus longipinnis, Acanthorhodeus gracilis, A. asmusii.*

15) Grooves circular

Misgurnus sometimes *Cobitis* in Cobitidae.

16) Network grooves formed in regenerated scales.

Carassius carassius, Leuciscus waleckii, apical grooves in *Coilia,* focal grooves of *Periophthalmus cantonensis, Tribolodon.*

And besides these, there are some species in Gobiidae whose outline of grooves is indistinct.

(4) **Ridges**

Though ridges have hitherto been called by the term 'circuli', they are not always circular, but often transverse, and even radial ones are to be seen. For this reason it

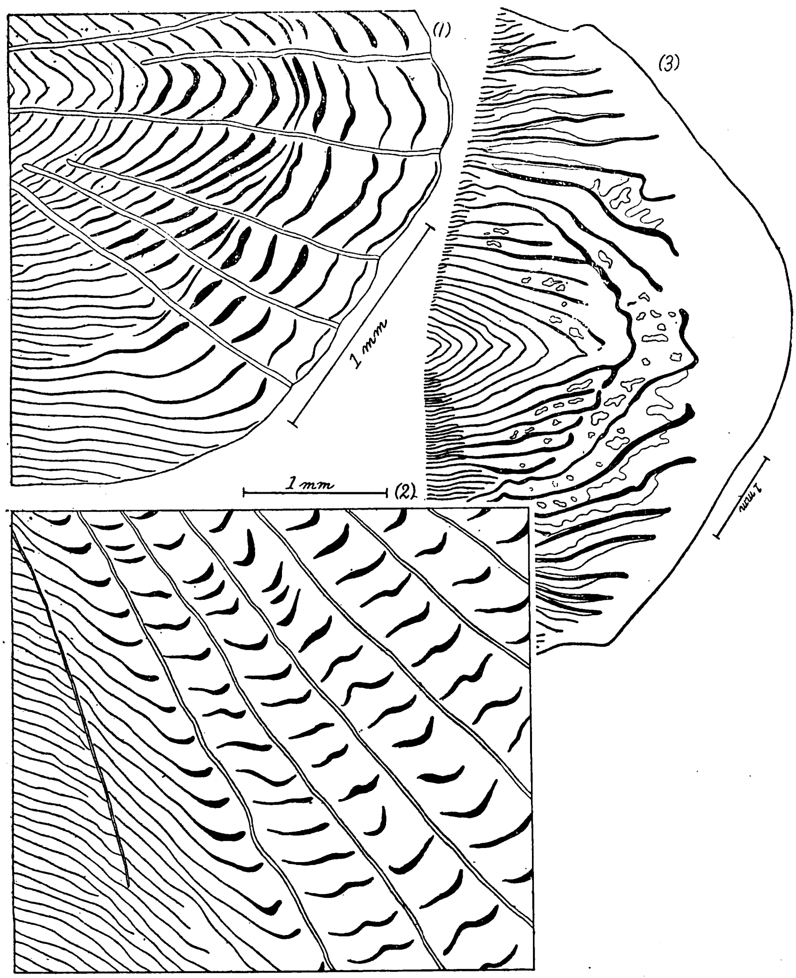


Fig. 2. Heavy apical ridges. (1) *Leuciscus waleckii,* 10cm, from s.c.p. Mûsan, Riv. Tûmen; (2) *Ophicephalus argus,* 31cm, from c.b.s., Corea; (3) *Ctenopharyngodon idellus,* 39.5cm, from c.b.s., Pond cultured fish.

would be proper to call them 'ridges', as was emphasized by the author (1950). The condition of ridges is as much varied as that of grooves, and there are many fishes which lack grooves and have ridges only, but scales with neither ridges nor grooves, viz., with no sculpture at all, can not be met with. A man with no finger or sole pattern is said to appear very rarely, but the author has never seen a sculptureless scale even exceptionally. Fishes with ridges in all the areas of scales, fishes with no apical ridges, with granulations which were once regarded as transformations of ridges, fishes with tubercles which are ridges transformed, fish with heavy ridges, fishes with branched ridges, fishes with network ridges, and other various transformations have been observed.

1) Ridges only; no grooves.

These are the same as those with no grooves at all mentioned above.

2) Ridges on the whole area of scales.

Coregonidae, *Oncorhynchus rhodurus. Salvelinus leucomaenis, Hucho,* Thymallidae, Osmeridae, Poecilidae, Cyprinodontidae, Hypophthalmichthynae, Leuciscinae except *Zacco* and *Opsariichthys, Ctenopharyngodon idellus,* Cyprininae, Cobitidae, Anguillidae, Hemirhamphidae, *Macropodus chinensis,* Ophicephalidae, Hemiramphidae, *Liza parva, Siniperca.*

3) Lacking most or all of the apical ridges.

Coilia, Clupanodon punctatus, some Salmonidae, Plecoglossidae, Acheilognathinae, Gobioninae, *Lateolabrax japonicus, Coreoperca, Therapon,* most of Gobiidae (Retained cycloid scales, *Periophthalmus cantonensis* and *Chaeturiichthys* excepted).

4) Heavy apical ridges. (Fig. 2)

Aplocheilus latipes, Aristichthys, Hypophthalmichthys, Leuciscus waleckii, Tribolodon hakonensis, Phoxinus, Ischikauia steenackerii, Ctenopharyngodon idellus, Ophicephalidae. *Micropterus salmoides, Siniperca shautsi, S. scherzeli.*

5) Transverse ridges.

Clupanodon punctatus, Plecoglossus altivelis, Osmerus dentex, Hypomesus olidus, Mugil cephalus, Leiognathus nuchalis, Sparus swinhonis.

6) Branched ridges.

Apicomedian ridges of *Hymenophysa curta,* sometimes *Phoxinus.*

7) Tubercles which are ridges transformed. (Fig. 3).

Carassius, Cyprinus carpio.

8) Granulations in the apical area. (Fig. 4.)

Most of Gobioninae in Cyprinidae.

9) With spawning mark.

Salmonidae, smetimes Plecoglossidae, *Hypomesus olidus.*

10) Ridges with minute spines. (Fig. 5.)

Mugillidae, *Therapon, Ophicephalus.*

11) Forming network ridges. (Fig. 6, 7,)

Posterior lateral ridges of Salmonidae, focal ridges of *Chasmichthys,* focal ridges

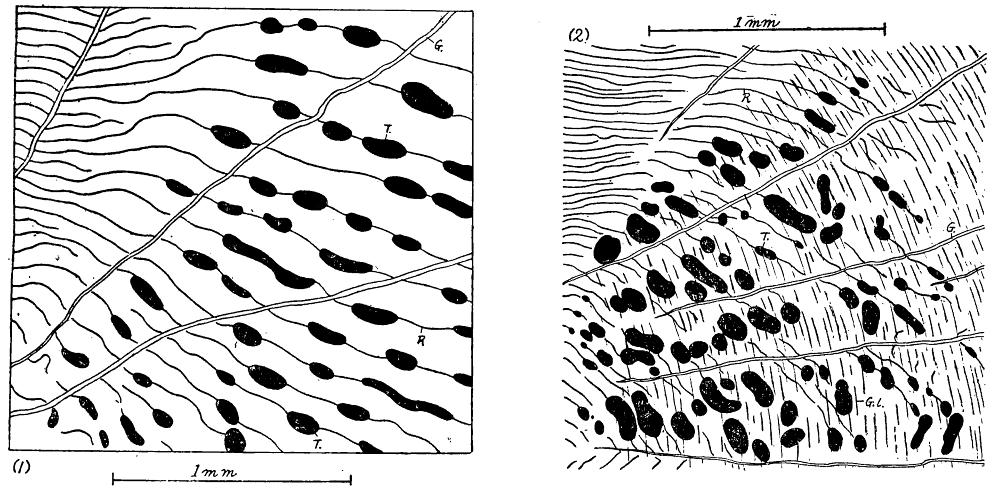


Fig. 3. Tubercles which are ridges transformed. (1) *Carassius carassius*, 31.5cm, from s.c.p.; (2) *Cyprinus carpio*, 13.5cm, from c.b.s.; Aburagahuti, Aiti Pref.
G. Groove, G.l. Growth line, R. Ridge, T. Tubercle.

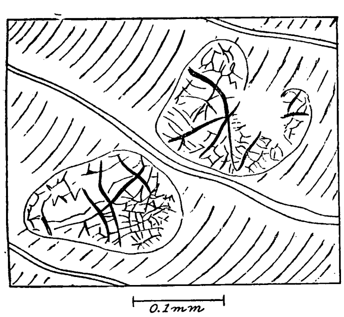
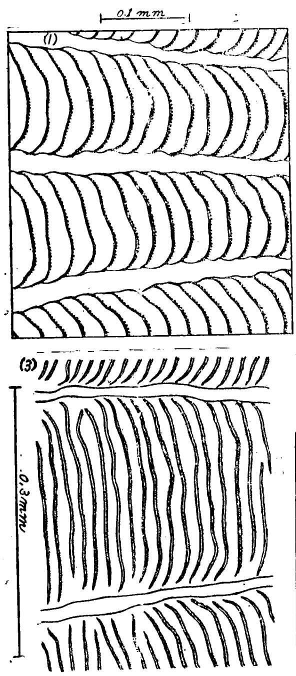


Fig. 4. Granulations of *Hemibarbus eristigma.* 11.7cm, from s.c.p., Tuyama, Okayama Pref.



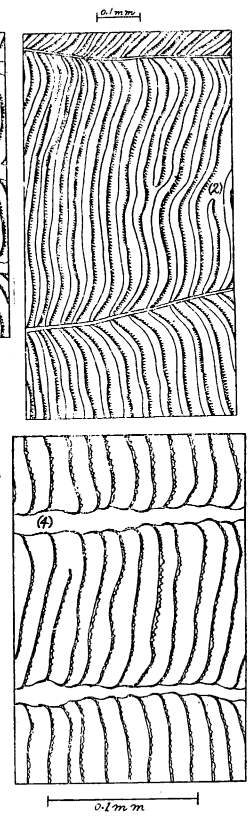
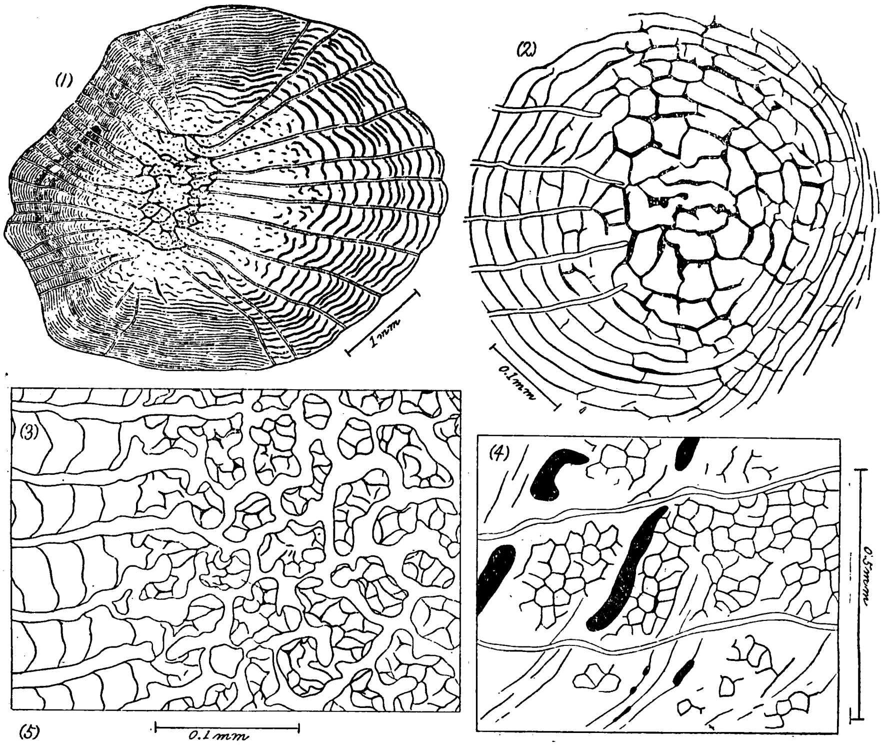
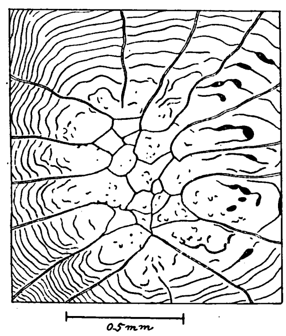
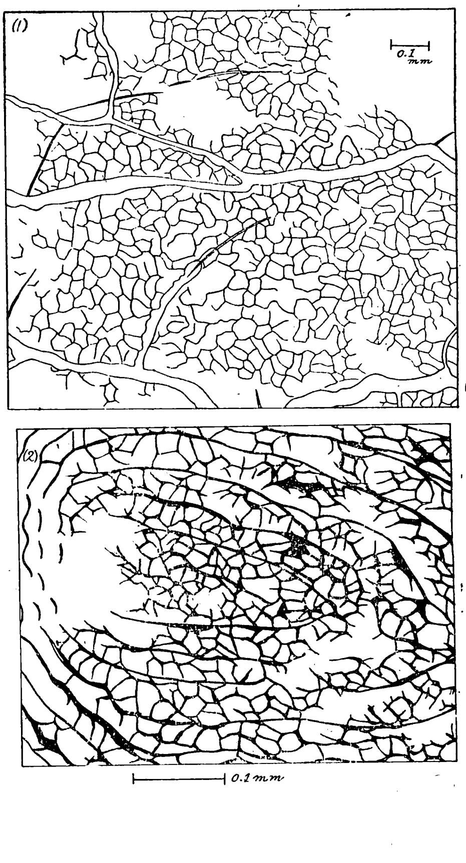


Fig. 5. Basal ridges with minute spines. (1) *Ophicephalus;* (2) *Mugil cephalus;* (3) *Therapon oxyrhynchus;* (4) *T. jarbua.*







↑ **Fig. 6.** Network ridges (1). (1) *Leuciscus waleckii*, body length unknown; (2) *Caeturichthis sciistius*, from s.c.p., Tu, Mie Pref.; (3) *Periophthalmus cantonensis*, 65cm, from Kariya, Aiti Pref.; (4) *Hemibarbus labeo*, 25cm, from s.c.p. Soochow Market, China; (5) *Carassius carassius auratus* (Goldfish), Focal area.

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Fig. 7. Network ridges (2). (1) *Ischikauia steenackeri*, 12.5cm, from c.b.s., Lake Biwa; (2) *Ophicephalus argus*, 17cm, from s.c.p., Harbin Market.

of *Periophthalmus cantonensis*, sometimes *Hemibarbus labeo*, regenerated scales of *Ischikauia steenackeri*, *Channa*.

12) Ridges transformed into many circles.

Anguillidae.

(5) Focus

The focus is distinct in almost all fishes, but it is sometimes hardly observable in some, and utterly unobservable in others, and there is a fish like Cobitidae which lacks sculpture in a pretty wide part around the focus. In such a case, the size is indicated by the proportion of the sculptureless focal area to the whole scale area, measured with a planimeter. A comparatively few have the focus in the geometrical center of scales, and many near it, and there are many cases, in which the focus is more or less apical or basal, remarkably basal or apical (in young scales of *Aplocheilus*, in the geometrical center), extremely apical or basal.

1) Focus central or subcentral.

Engrauridae, Dorosomatidae, Coregonidae, Salmonidae, Plecoglossidae, Thymallidae, Cyprinodontidae, Anguillidae, Hemirhamphidae, Ophicephalidae, *Coreoperca kawamebari*, *Siniperca chautsi*, *Siniperca scherzeli*, *Periophthalmus cantonensis*, *Pseudoperilampus typus*, *Acanthorhodeus gracilis*, *Rhodeus ocellatus*, *Hypophthalmichthys molitrix*, *Carassius*, *Cyprinus*, *Hemigrammocypris rasborella*. Centrarchidae, Kuhlidae, Leiognathidae, *Mugil cephalus*, *Liza parva*.

2) Focus basal.

Most of Cyprinidae, Osmeridae and Cobitidae.

3) Focus apical.

Macropodus chinensis, *Mugil carinatus*, *Coreoperca herzi*, Theraponidae, *Periophthalmus cantonensis*, *Sicyopterys japonicus*, *Chaeturiichthys sciistius*, *C. hexanema*, *Chasmichthys dolichognathus*, *Pterogobius elapoides*.

4) Focus extremely apical or situated close to the apex.

Most of Gobiidae (often the focus joining the apex).

5) Focus whose situation is unknown.

Lefua, *Cobitis* in Cobitidae

6) Focus extremely basal.

Coreoleuciscus splendidus (anterior 1/10 of scales), *Biwia zezera* (more to the front than anterior 1/7), *Gnathopogon gracilis* (in a s. c. p. scale, sometimes coming to anterior 1/13),

(6) Growth Iines

Some fishes have growth lines in the apical area, which differ from ridges in nature and are caused by the density of the substance of scales. That growth lines are very different in nature from ridges, was already clarified by CHU, Y. T. (1935), and KOBAYASI, H. (1937). The reason why they are distinct only in the apical area and indistinct or utterly unseen in the other areas, is unknown. Growth lines are distinct in fishes of Cyprinidae, invading the lateral area, and, in some extreme cases, indistinctly observable even in the basal area.

In most of Cyprinidae, growth lines are distinctly observable, while their existence is indistinctly observed in *Coilia, Oncorhynchus rhodurus, O. masou, Clupanodon punctatus, Osmerus dentex, Sparus swinhonis* etc., and in some marine fishes, they are also observed.

Growth lines differ from ridges in that they are seen running parallel with the apical margin, and when the apical margin is waved, growth lines are also waved, and when both exist within the same sight, they are clearly distinguishable.

(7) Lateral Line Scales

Needless to say, a line of scales with mucous tubes, which are lateral line organs, is called a lateral line, and this line may be complete or incomplete, some fishes utterly lacking it. It is also interesting to find fishes with small mucous tubes in all scales of the body. In *Gnathopogon,* lateral line scales are much more greater in breadth than other scales, and as a whole of greater size.

1) No lateral line at all.

Lefua echigonia, Cobitis, Aplocheilus latipes, Gambusia affinis, all Gobiidae, sometimes *Pseudoperilampus,* sometimes *Rhodeus.*

2) Incomplete lateral line.

Hemigrammocypris rasborella, Rhodeus ocellatus, Pseudorasbora parva pumila, Tanakia, Pseudoperilampus typus, Misgurnus, Lefua nikkonis, Osmerus dentex, Spirinchus lanceolatus, Hypomesus olidus.

3) Lateral line broken halfway.

Ophicephalidae.

4) Mucous tubes in all scales of body (in adult fishes only).

Mugillidae.

(8) Spines in Ctenoid Scales

The condition of arrangemeut of spines can roughly be observed in three types.

1) Commonest radial series types. (Fig. 8.)

Anabatidae, Kuhlidae, Serranidae, Sparidae, Theraponidae.

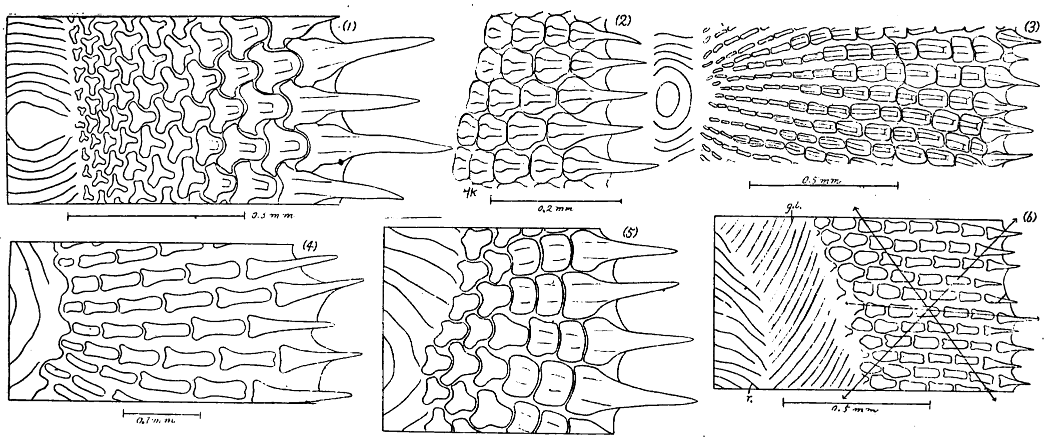
2) Rasp type. (Fig. 9.)

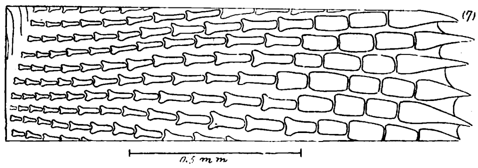
Mugillidae, Centrarchidae.

3) Single belt-line type. (Fig. 10.)

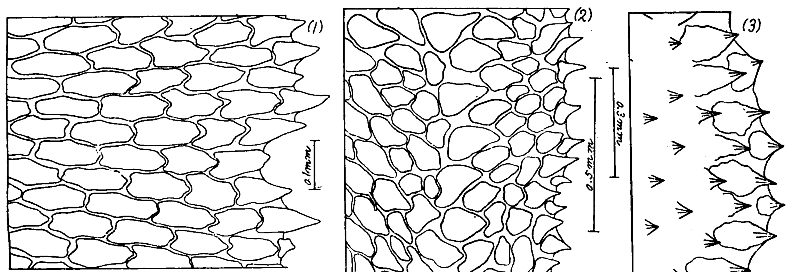
Most of Gobiidae.

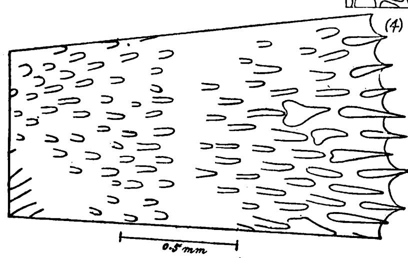
In scales of Mugillidae, spines seem to have been formed, like tubercles of Cyprininae, by the destruction of ridges. The condition of the spines of ctenoid fishes including all their families, will be summarized as follows. Spines of Mugillidae, firstly in *M. cephalus,* have large broad roots and are sharply pointed in the early stage of developnent, but those of larger fishes, formed without number, are rootless and bluntly pointed, but in *M. carinatus* and *Liza menada,* they have roots, only marginal spines being sharply pointed, and many other anterior ones pointless, and they make radial series on the whole, but the series are rather in disorder and tend to be





↑ **Fig. 8.** Radial series type spines. (1) *Therapon oxyrhynchus*, 21.1cm, Hiwasa, Tokushima Pref.; (2) *Macropodus chinensis*, 4.5cm, from c.b.s., Atumi Bay; (4) *Sparus swinhonis*, 8.6cm, from s.c.p. Iridemura, Lake Hamana; (5) *Therapon jarbua*, 8.3cm, River Kedo, Makerazaki-si, Kagosima Pref.; (6) *Sparus swinhonis*, 12cm from c.b.s., Yaizu, Sizuoka Pref.; (7) *Kuhlia marginata*, 10.3cm, Takao (o.m.), Formosa. g.l. Growth line, r. Ridge ((2), Kobayasi. 1950)





←**Fig. 9.** Rasp type spines. (1) *Mugil carinata*, 13.8 cm, from s.c.p. Formosa; (2) *Liza menada*, 34.5cm, from s.c.p., Yaizu, Sizuoka Pref.; (3) *Mugil cephalus*, 10cm, from c.b.s., Tenryûgawa; (4) *Micropterus salmoides*, 17cm, from c.b.s., Lake Asi.

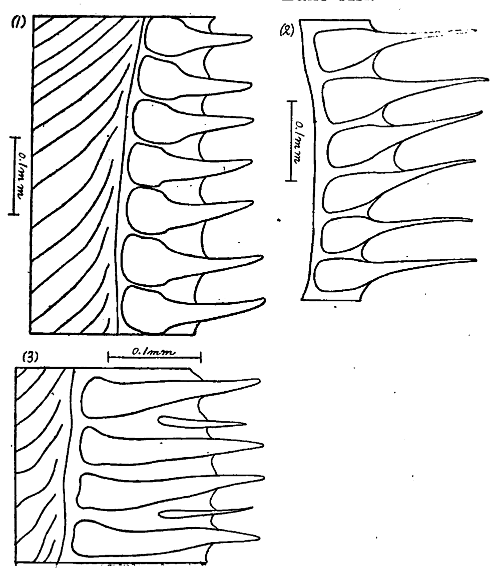


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Fig. 10. Single belt-line type spines. (1) *Eleotris swinhonis*, 4.5cm, from c.b.s., Lake Taihu; (2) *Gobius formosanus*, from c.b.s. Formosa; (3) *Tridentiger obscurus*, 9.8cm, from c.b.s., Uraga-cyô, Hidaka Prov., Small incomplete spines are added.

irregular. In those which show regular arrangement, radial and two oblique series are observable.

Then scales of *Macropodus* in Anabatidae make regularly radiated series, marginal spines being sharply pointed, many anterior ones all pointless, and the foremost ones simply spot-like. In *Micropterus* of Centrarchidae, radial series are indistinct, making irregular arrangement, and marginal spines are sharply pointed, with small roots, while many anterior ones are blunt and rootless. Those of Kuhlidae make regularly radiated series, marginal spines are sharply pointed, with roots inconspicuous, and many anterior small spines are roots only, densely spread all over the apical area. In *Lateolabrax* of Serranidae, marginal spines are larger than those of Kuhlidae though simiar to them, while in Sparidae radial and two oblique series are distinct, showing regular arrangement. In Theraponidae, radial series are distinct, marginal spines being large-sized and their roots also very large-sized and sharply pointed, and anterior ones are pointless, and smaller-sized when compared with marginal spines. In Gobiidae, they form a single belt-line type as above stated, but often incomplete spines are added to them, some times making several lines. (Fig. 11.) It is common that spines are sharply pointed, and become smaller-sized toward the apex, their points being often curved inward. And phylogenetical relation is considered to exist also in the arrangement, form and number of spines.

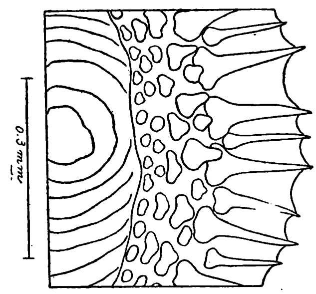

Fig. 11. Spines of *Mogurnda obscura*. 12.8cm, from c.b s. Tinan (o. n.), Corea.

That ctenoid scales with spines are more evolved in form than cycloid scales, can be understood by observing the development of scales. And from such relations, the consideration of phylogeny seems to be made possible.

(9) **Regenerated Scales**

Regenerated scales are, when compared with ordinary scales, clearly distinguishable. Generally the sculpture in the focal area is disordered or a sculptureless focal area sometimes appears, or a reticular structure is shown. But it should be noticed that in *Lefua* and *Cobitis* in Cobitidae, ordinary scales have an extensive sculptureless area.

Regeneration takes place so rapidly that acccrding to the experiment on Goldfish, regenerated scales are already formed within 10 days and are completed within a month. When scales falling off, regeneration takes place in the eary stage of development of fishes, only a small area of disordered sculpture is observed in the focal area, but when, as fishes grow up, regeneration is delayed, this disorder is enlarged into an extensive area. It was reported by my student SUZUKI R. (1952) that ast ime passes, this disordered sculpture in regenerated scales gradually returns to the structure of ordinary scales, until at last they come to be utterly indistinguishable. In some fishes of wild species, most of the scales are regenerated ones, ordinary scales being difficult to find out. In *Salvelinus* and Gobiidae, such instances are frequently met with. This is the subject related with the oecology of fishes, but strange to say, though in scales of *Sicyopterys* in Gobiidae, scales are hard to strip off and difficult to collect, nearly all the scales are regenerated ones, ordinary scales being difficult to find out.

Regenerated scales are sometimes entirely different from ordinary ones in form and structure. Firstly, e. g., the apical margin of ordinary scales is usually projected backward in > shape, but that of regenerated scales is gently swelled out, the apex being invariably not projected. And then there are some whose regenerated scales form anastomosing network grooves like those of *Leuciscus* in Leuciscinae or *Carassius*, and this is the key to consider the phylogenetic relation between Leuciscinae and Cyprininae, which the author already pointed out (Jap. Jour. Ichthyol., Vol. 2, No. 1, 1951) and will later describe in detail.

(10) Scale Arrangement

Scale arrangement, in Teleostomi, is generally regular, overlapped in tiled-roof form, excepting Anguillidae in which mosaic arrangement is made (KOBAYASI, H., 1939). It is natural that scales of *Anguilla* are, judging from their natural position, not so simple as other common scales in considering the anterior, posterior, upper and lower sides of them.

(11) Phylogenetical and Evolutional Significance of Scale Character

As the author mentioned in the introduction, scales are precious materials in considering the affinity between fishes, which was described in his previous paper (Jap. Jour. Ichthyol., Vol. 2, No. 1, 1951) as follows :

"...... I come to this conclusion : that, where any two fishes are similar in scale character, their affinity is close and where they are not similar, their affinity is distant. In short, affinity can be guessed from the extent of similarity in scale character. Furthermore, where any two fishes which are alike in appearance are different in scale character, their affinity may be distant in reality notwithstanding their apparent nearness. On the other hand, where they are closely similar in scale character, although their appearances are not so alike, a close affinity may be assumed and the further careful examination of other sort of character should be required".

From the standpoint of comparative morphology in scales of an individual species or a larger group, the author came to the conclusion mentioned above, but furthermore the phylogenetical and evolutional significance of scale character will be considered. Firstly, as to the relation between cycloid and ctenoid scales, it is lepidologically proved that cycloid fishes are more primitive than ctenoid fishes. From the embryological point of view, ctenoid scales in their early stage of development all start from cycloid scales and with their development going on, spines begin to be formed, and then the fishes gradually grow up to be adult, until they are changed into perfect ctenoid fishes. There are a good many ctenoid fishes with cycloid scales retained in some parts of body, showing their ancestral character. This is a good example to prove the relation mentioned above.

Scales with ridges only and no grooves, are more primitive than those with both grooves and ridges, for young scales have ridges only, but grooves are formed by degrees, viz., grooves are a structure formed later than ridges. No scales with grooves only and no ridges at all, can be found, but there are many primitive fishes which have ridges only and no grooves at all.

When scales of *Macropodus chinensis* are observed according to the foregoing consideration, they have cycloid scales with ridges only, cycloid scales with both ridges and grooves, and ctenoid scales with ridges, grooves and spines; indeed, the fish is of lepidologically deep interest, haveing the above-mentioned phylogenetical proof in every part of the body.

When partially discussed, e. g., in Salmonidae, scales are grooveless, most primitive ones haveing circular ridges all over the areas, and then apical ridges are gradually degenerated, until they are evolved into the direction of entirely lacking them; and when anastmosing network ridges grow in the posterior part of lateral ridges, degeneration is considered to have reached its climax. This is to be understood by examining the process of development of scales of *Oncorhynchus masou,* etc. Scales of all the young fishes of Salmonidae start from those haveing ridges on the whole area of them, some retaining this character, having ridges on the whole area of scales, after they have become adult ones, and then as above stated, there are also seen various degrees of degeneration of apical ridges and of formation of network ridges, enabling the phylogenetic and evolutionary relation between species in Salmonidae to be considered by these facts.

Such a phenomenon is not only to be seen in Salmonidae, but also in all the groups of fishes, the author believes. Moreover, it has already been proved by many scholars that within the same species the oecology of fishes is shown in scales and that the sculpture carved on scales is the key to know the race of fishes.

Scales character thus reflects the condition of life history of fishes and also indicates the standard of their systematics or classification on one hand, and what is more important on the other, being an excellent material to explain the relation of phylogeny, it is of utmost importance in ichthyology, the author must especially emphasize. This paragraph shall be finishes by stating that HAECKEL's biogenetic or recapitulation law also applies to the development of scales.

(12) Phylogenetical Relation in Scale Character between Japanese Species and Asian-Continental Ones

Among the Japanese freshwater fishes, true freshwater fishes with no relation to marine fishes, all have their origin in the Continental species, and after separation of the Japanese Islands from the Continent, they were geographically isolated from the Continental ones, until they have been evolved into the present ones proper to Japan; and this can be understood from the standpoint of scale character or lepidology. This relation is to be understood by comparing the photo or figure of Chinese Cyprinids in

CHU's paper (1935) with that of Japanese Cyprinidae in the authors (1937–1938). Though such fishes as *Tanakia, Biwia, Ischikauia, Hymenophysa*, etc. are regarded as genera or species proper to Japan, it is known by scale character that all of them have their origin in the Continental species. In other words, when the affinity among these genera or species is examined by the resemblance of scale characther, they are all related with the Continental species or with the common species to Japan and the Continent. This tendency is strong in Cyprinidae and Cobitidae, and the author may conclude that all the fishes within these two true freshwater families had the same ancestor in the Continental species in the near past.

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