The definite localization of the color pattern in the goldfish.

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With 29 text figures.

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1. Introduction.

As was shown in my previous paper¹⁾, the black pattern of the goldfish is produced always in the definite localizations in experiments as well as under normal conditions. Red pattern is distributed in the same way. In order to see what determines the distribution of the red and black patterns, observations were made on several white goldfish with red pattern and three black-backed ones, all of which were 5 or 6 cm long exclusive of the caudal fin.

After careful examinations one interesting fact was found that the spreading of the pattern always corresponds to the extent of one or many bones in the head and to some scales or scale lines in the trunk.

1) K. Fukui, *Folia Anatomica Japonica*. Bd. 5, 1927.

2. Abbreviations used for different regions of goldfish.

The following abbreviations are used throughout the present paper to indicate various regions (Fig. 1.):

Fig. 1.

- A. Head Each part nearly corresponds to the extent of the bone under the skin.
- H. 1 Pm (premaxillary); Ma (maxillary); Me (mesethmoid);
- H. 2 Fr (frontal); Spb (supraorbital); Pf (postfrontal); Sbb (suborbital);
- H. 3 Soc (supraoccipital); Pa (parietal); Pt (pterotic); Sop (superior part of the operculum); Op (middle part of the operculum); Iop (inferior part of the operculum); Sbb (subopercular); Pro (preopercular); Ito (interopercular).

B. Trunk Each part is represented by the names of its corresponding scales or scale lines in the skin.

a) The longitudinal scale lines.

Lsl The scale line bearing the lateral canal system.

Dal (Val) The dorsal (ventral) scale line next to Lsl.

Db1 (Vbl) The dorsal (ventral) scale line next to Dal (Val).

Dcl (Vcl) The dorsal (ventral) scale line next to Db1 (Vbl). Etc.

b) The number of each scale.

The scales on Lsl are numbered from its cranial end like Ls 1, Ls 2, etc.

The scale on Dal (Val) after Ls x is numbered Das (Vas) x'.

The scale on Db1 (Vbl) before Das (Vas) x' is numbered Dbs (Vbs) x.

The scale on Dcl (Vcl) after Dbs (Vbs) x is numbered Dcs (Vcs) x'.

c) The transverse scale lines.

Dvl x (x') The dorso-ventral scale line along the scales numbered x (x').

d) The oblique scale lines.

Dp (Vp) - Obl x The dorso (ventro) — caudal scale line starting at Ls x.

Dn (Vn) - Obl x The dorso (ventro) — cranial scale line starting at Ls x.

3. Observations on color pattern.

1) Specimen No. 71. (Fig. 2. & Fig. 3.)

The black pattern of this fish consists of two typical bands, one along the dorsal median line from the anterior end of H.3 to the caudal fin and the other along the boundary between B.1 and B.2. On the right side the middle part of the longitudinal band entirely lacks black pigment on the part of B.2, between Dvl 7' and Dvl 18' and the band is separated into two parts. On the left side it is continuous through the back, and its portion on B.2 is specially conspicuous. The posterior part of this band on B.3 and B.4 spreads ventrally to Dcl symmetrically on both sides, though its cranial end is at Dvl 19 on the right and at Dvl 21 on the left.

Its anterior part on H.3 and B.1 varies somewhat in extension on each side of the body. On the right side it makes a narrow band with an equal width through its entire length, covering almost one or two scales on the dorsal median line. On the left side it makes a triangle widening gradually caudally, whose ventral margin passes along Ddl and whose base stretches ventrally just along Dvl 7 as far as Vbl over

the lateral line. The middle part of the longitudinal band, which exists merely on the left side, spreads chiefly along Ddl, though it projects both dorsally and ventrally in different parts.

Fig. 2.

Fig. 3.

2) Specimen No. 72. (Fig. 4. & Fig. 5.)

This white fish bears black and red patterns symmetrically on both sides of the body. In the head the black pattern covers the parts of Soc, Pa and Pt, and on the back it reaches the caudal end of the dorsal fin, stretching along the dorsal scale lines except Dbl and Dal, and extending also more ventrally to Dbs 5-9 and Das 6'-9' on the right side and to Dbs 7-19 and Das 11'-12' on the other.

The red pattern spreads all over the margin of the black one. In

the head it penetrates into Fr, Spb, Pf, Sop and Op. On the trunk it makes a wide spreading over the abdominal bulge. On the right side its anterior margin runs along the dorsal side of the anterior four scales of Lsl and then along Vp-Obl 5 until Vel, while its posterior margin runs along the ventral side of posterior six scales of Lsl and of Vas 18'-19' and then along Dvl 17. On the left side its anterior margin runs from the anterior end of Dbl to Dcs 5' and then along

Fig. 4.

Fig. 5.

Dvl 7, while its posterior margin runs along the ventral side of posterior five scales on Lsl and along Vn-Obl 20 to Vcl and then along Vn-Obl 19.

3) Specimen No. 73. (Fig. 6. & Fig. 7.)

This black-backed fish has the symmetrical black pattern on both sides. In the head it is limited to the peripheries such as the jaws, the dorsal margin of both eyes and nasal lids, and the ventral part of the opercula. And it is also limited to the dorso-caudal end of the head,

Fig. 6.

Fig. 7.

making the tip of a triangle, whose ventral margin runs ventro-caudally across the middle of both Pa and Pt and then along Dbl on B.1. On the trunk it spreads very widely over the entire flank except a small area just along its cranial end. On the right side it is marked by a ventro-cranial scale line from Dbs 5 to Vbs 3 and then by Vp-Obl 3 from Vdl to Vf1. On the left side its margin corresponds nearly to the ventro-caudal scale line across Ls 7.

4) Specimen No. 74. (Fig. 8. & Fig. 9.)

The red pattern of this fish is limited to the ventral half of the body. On the head it covers both the opercula besides both Pt and left Pf. On the right side of the abdomen it reaches Vcl, on the other side

Fig. 8.

Fig. 9.

Val, and also covers right Vbs 17-18 and left Ls 10. Its anterior margin runs on the right side along Vn-Obl 7 and on the left side along Dvl 5. Its posterior margin runs on the right side along Dvl 18, while on the left side it makes an angle at Vcs 19', stretching dorsally along Dp-Obl 18 and ventrally along Vn-Obl 21.

5) Specimen No. 75. (Fig. 10. & Fig. 11.)

The red pattern of this fish spreads rather dorso-ventrally along the boundary between the head and the trunk. In the head it covers almost the entire region of H.3, excepting its ventral end. On the back it is limited to the anterior end of B.1, covering only those scales anterior

Fig. 10.

Fig. 11.

to Dvl 3 on the right side and those at the cranio-dorsal end of the left side.

6) Specimen No. 76. (Fig. 12. & Fig. 13.)

In addition to the dorsal margin of the eyes and to left Sop, the red pattern of this fish spreads on the dorsal part of both H.3 and B.1, covering in the head Soc, Pa, Pt on both sides and left Pf, and on the back all the scales anterior to right Dp-Obl 5 and to left Dp-Obl 6, except Dal.

Fig. 12.

Fig. 13.

7) Specimen No. 77. (Fig. 14. & Fig. 15.)

The red pattern of this fish spreads along the dorsal part of the body from the anterior end of H.3 to the posterior end of the dorsal fin. In the head it covers Soc, Pa and Pt on both sides and left Sop. On the right back it covers all the scales anterior to Dp-Obl 15' except a few on Dal, extending caudally to Dbs 19 and to Dcs 21'. On the left back it covers all the scales anterior to Dp-Obl 8, extending not only caudally to Dbs 12 and Dcs 21', but also ventrally to Vbl along Dvl 6 and Dvl 7.

Fig. 14.

Fig. 15.

8) Specimen No. 78. (Fig. 16. & Fig. 17.)

The red pattern of this fish spreads over the dorsal part of the body from H.3 to B.3. On both sides of the head it covers Soc, Pa and Pt. On the right back it covers all the scales anterior to Dp-Obl 13, extending caudally to Dbs 16, Dcs 26', Dds 27 and ventrally to Ls 12 and Ls 13. On the left back it spreads all over the scales anterior to Dp-Obl 23, anterior four scales on Dal, Das 12'-16', Dbs 13-15 and Das 22' excepted, and extends ventrally to Ls 6-12 and Vas 6'-8'.

Fig. 16.

Fig. 17.

9) Specimen No. 79. (Fig. 18. & Fig. 19.)

The red pattern of this fish covers the dorsal part of the body from H.2 to B.3. In the head it spreads over Soc, Pa, Pt, Pf and Spb of both sides besides Sop and the left nasal lid. On the right back it covers all of the scales anterior to Dp-Obl 22 except Dal, and extends ventrally to those scales on Dal and Lsl anterior to Dp-Obl 13, and to Vas 7' and Vas 8. On the left back it covers all of the scales anterior to Dp-Obl 22 except Das 2'-4' and Das 22', extending to Ls 6-16 und Vas 7'-14'.

Fig. 18.

Fig. 19.

10) Specimen No. 80. (Fig. 20. & Fig. 21.)

The red pattern of this fish spreads from H.2 to B.2. In the head it covers the nasal lids, Fr, Spb, Pf, Soc, Pa, Pt and Sop on both sides, and both Sbo and right Pro are also colored red. On the right back it spreads over the scales anterior to Dp-Obl 12 except Dal and Dbl, extending ventrally to those scales on Dal and Dbl anterior to Dp-Obl 6, and to Ls 1-3 and Vas 1'-2'. On the left back it spreads over the scales anterior to Dvl 15 except Dal and Dbl, extending ventrally to Vdl all over the scales anterior to the oblique scale line running ventro-cranially across Ls 8.

Fig. 20.

Fig. 21.

11) Specimen No. 81. (Fig. 22. & Fig. 23.)

The red pattern of this fish entirely covers the dorsal half of the

body. It covers both sides of the head except Sbb and the opercula, and stretches ventrally along the caudal margin of the latter till it reaches Sop on the right side and Sbo on the left. On the right back it covers all of the scales dorsal to Lsl except those on Dal, Das 3'-4', 7'-9', 11'-12', 18'-20'. It covers Ls 1-2, Vas 1' and Ls 26 at both ends of Lsl. On the left back it spreads all over the dorsal scale lines and Lsl anterior to Dp-Obl 14, exclusive of Ls 10 and Ls 13, and extends caudally to other dorsal scales excepting Dbs 16-19 and Das 15'-21' and to Ls 23. Also it makes two ventral projections beyond Lsl, anteriorly over Vas 5'-8', Vbs 7-8, Vcs 7' and posteriorly over Vas 11'-13', Vbs 14.

Fig. 22.

Fig. 23.

12) Specimen No. 82. (Fig. 24. & Fig. 25.)

In the head of this fish such parts are excluded from the red pattern as right Pf, Sbb and the opercula excepting Spo on both sides. On the right back it covers the scales anterior to Dp-Obl 5 except Das 4'-5', and those between Dn-Obl 10 and Dp-Obl 14 except the scales dorsal to Del, and between Dn-Obl 18 and Dp-Obl 23 except Das 22'. It makes also a ventral projection beyond Lsl at Ls 8-12, Vas 7'-11' and Vbs 9-11. On the left back it disappears entirely on B.2, covering only those scales anterior to Dvl 6 except Dal and those between Dn-Obl 19 and Dp-Obl 25 except Das 18'-19', besides Ls 24.

Fig. 24.

Fig. 25.

13) Specimen No. 83. (Fig. 26. & Fig. 27.)

The red pattern of this fish is separated into two parts. The anterior part is symmetrical on both sides, limited to Soc and the scales anterior to Dp-Obl 1. On the right back it makes a longitudinal band covering each dorsal scale line from Dds 13, Dcs 11' and Dbs 19 to the caudal end, and projects ventrally beyond Lsl at its both ends. The anterior projection reaches Vds 13, covering the scales on the scale lines from Dbl to Vcl between Dvl 11 and Dvl 14, though Ls 12 and Vas 12' are outside of the pattern. The posterior projection stretches along the base of the caudal fin, covering the scales from Das 23', Ls 25 and Vas 25' to the end of each corresponding scale line. On the left back the posterior pattern covers all dorsal scales existing caudal of Dvl 16 except Das 19' and Das 22' and covers Das 15'. On the other side its caudal end projects ventrally beyond Lsl along the base of the caudal fin, covering Ls 25, Vas 25', Vbs 26 and the scales caudal of them.

Fig. 26.

Fig. 27.

4. General results.

From the above observations it may be deduced that both the black and red patterns of the goldfish spread in the same way and always take a definite distribution as I mention in my previous paper. They are distributed along the dorsal or the ventral median line, or just along the ventral side of the lateral canal system running through the trunk and the head, and so they are separated into the dorsal, ventral and lateral patterns respectively.

The dorsal pattern is usually limited to the dorsal side of the lateral canal system, though it sometimes spreads ventrally beyond this canal. The boundary between the other two patterns which are on the ventral side of the same canal are very obscure, but the original ventral pattern appears along the bases of those fins as a pair along the ventral median line and the lateral one is limited to Sbb and the operculum in the head and to the middle of the abdominal bulge.

In the trunk the lateral canal system runs as the lateral line along Lsl through the middle of the flank, but it is separated in the head (Fig. 29)¹⁾. According to my observation, in the case of the goldfish, the direct continuation of the lateral line runs craniad, at first through the junction between Pt and Sop and then through the junction between Fr and Spb till it reaches the nares. From this stem at least two dorsal and three ventral branches come out always along the margin of a bone or along the junction between two bones over the head. The caudal one of the dorsal branches goes dorsally along the caudal margin of both Pt and Pa and the cranial one along the junction between Pa and Pt. The caudal one of the ventral branches runs ventrally to the mandibular region, covered by the caudal and the ventral margins of Sbb. The middle one of them takes its course cranially across Pf and the dorsal part of Sbb and then cranially along the dorsal margin of Sbb to the jaw. The cranial one goes ventrally along the boundary between Spb and Pf to the dorsal margin of the orbit.

The dorsal pattern of the head is usually limited to the dorsal side of these branches. When it is small, it is limited to the snout, sometimes merely on the jaws and sometimes over the whole region of H.1, or to the dorsal end of H.3, sometimes merely over Soc and sometimes over both Soc and Pa. In these cases the color pattern is always on the dorsal side of all the branches of the lateral canal. The dorsal

1) See p. 305.

pattern produced on the snout never spreads ventrad over the lateral canal along the dorsal margin of Sbb, and its caudal extension from H.1 to Fr is also seldom. But the dorsal pattern on H.3 spreads both craniad and ventrad over the margins of Soc and Pa. When it spreads craniad to Fr, it does not cover any branch of the lateral canal. More frequently does it spread ventrally beyond the branch of the lateral canal along the junction between Pa and Pt, and reaches the ventral margin of the latter bone where the stem of the canal passes. In this case the spreading of the dorsal pattern is always limited to the region H.3, even when it projects to Sop beyond the stem of the lateral canal between Pt and Sop. On the contrary, the cranial extension of the dorsal pattern from Pa to Fr means its spreading beyond the boundary between H.2 and H.3. Usually the dorsal pattern on Soc and Pa spreads beyond the boundary between H.2 and H.3 and the junction between Pa and Pt both cranially and ventrally. So its ventral margin corresponds to the passage of the stem of the lateral canal; between Pt and Soc and between Fr and Spb. The ventral projection of the dorsal pattern beyond the stem of the lateral canal is repeated in three parts. On H.3, it goes along the caudal margin of the operculum, sometimes limited to Sop and sometimes spreading far ventrally to the ventral end of Op or Iop. On H.2, it can be limited to Spb, stretching cranio-ventrally along the cranial margin of the orbit, or it can cover both Spb and Pf beyond the branch of the lateral canal along the boundary between these two bones, stretching ventrally not only along the cranial margin of the orbit but also along its caudal margin bordered caudally by the middle ventral branch of the lateral canal running obliquely across the dorsal part of Sbb.

Thus the dorsal pattern in the head originates from two different centers. The dorsal pattern on the snout spreads from its center on the jaw and is limited to H.1. This may be called the "snout pattern". The dorsal pattern on the head itself has its center on Soc, whence it spreads sometimes ventrally within the limit of H.3 and sometimes cranially and ventrally over the dorsal half of both H.2 and H.3. It may be called the "head pattern" in the narrow sense.

The lateral pattern in the head covers the operculum and Sbb. It may be designated the "opercular pattern". Sometimes it covers the whole extent of the operculum within the limit of H.3, but sometimes it covers the ventral part of the operculum and stretches craniad along the ventral margin of Sbb, beyond the boundary between H.2 and H.3. Though it is not ascertained where the center of this opercular

pattern exists, the small pattern is sometimes limited to Sbo or to the part along the junction between Sbo and Pro, and the larger one covers Iop besides these bones, stretching dorsad along both margins of Op, which makes a prominence in the middle of the operculum. In other cases the small spot is produced on Sop or on either side of the junction between Op and Sbb. The former is usually limited to Sop, but the latter may spread over Op and the dorsal part of Sbb beyond the junction between both bones, i.e., beyond the boundary between H.2 and H.3. Therefore the opercular pattern is to be separated into the dorsal, lateral and ventral parts, according to different origins. Its dorsal projection to Pt and Pf beyond the lateral canal system along the dorsal margin of Sop occurs in the specimen No. 74.

Usually the dorsal pattern of the trunk covers the dorsal scale lines, but sometimes extends to the scales on Lsl or on the ventral scale lines beyond the lateral line. The smallest of this pattern is produced either at the cranial end of the back or between the dorsal and the caudal fins just on the dorsal median line. But generally the former unites with the small spot on Soc in the head along both sides of the boundary between the head and the back. It corresponds to the center of the dorsal pattern on B.1, which spreads caudad and ventrad. When it spreads caudally, it makes a longitudinal band between the head and the dorsal fin, and in other cases, a transverse band along the cranial end of the back. The caudal end of the longitudinal band may almost reach Dvl 7, corresponding to the boundary between B. 1 and B. 2, and the ventral end of the transverse band is usually on the dorsal side of Lsl. Thus the dorsal pattern spreading from the center at the dorsal end of the cranial margin of the back is generally limited to the cranial part of the back bordered caudally by Dvl 7 and ventrally by Lsl. This may be called the "neck pattern". Generally the neck- and the head-patterns are produced at the same time as a continuous pattern, and it is probable that these two patterns come from one and the same center where the dorsal median line and the boundary between the head and the back cross to each other. From this center pigmentation may spread symmetrically along both sides of the dorsal median line and of the boundary between the head and the back.

The small spot on the dorsal median line between the dorsal fin and the caudal fin corresponds to the center of the dorsal pattern on B.3. It spreads ventrad to Lsl and cranial near the caudal end of the dorsal fin, and so it comes to cover all dorsal scale lines on the tail. Its cranial extension reaches somewhere between Dvl 16 and Dvl 19, and its caudal

end corresponds approximately to the end of the back except a few scales just along the base of the caudal fin. But the dorsal pattern on B.3 often unites with that on B.4, which appears at first as a little spot on the dorsal margin of the caudal fin, and may cover all of the tail except the scales just along the base of the anal fin. So the pattern on B.3 may be called the "tail pattern", sometimes including also the pattern on B.4, which may be specially designated the "terminal pattern". The tail pattern sometimes stretches ventrad at its cranial end, making a projection beyond Lsl and then in the furrow along the caudal margin of the abdominal bulge. And when it unites with the terminal pattern, it often stretches ventrad beyond Lsl along the base of the caudal fin.

The dorsal pattern limited to B.2 is relatively seldom, and it disappears just in this region even when it covers all other regions of the back. But the isolated dorsal pattern is sometimes produced on this part, appearing at first at its center on the dorsal median line just before the anterior end of the dorsal fin and spreading either caudally along the base of the dorsal fin or ventrally along the line drawn to the base of the ventral fin. When it stretches to one direction only, it assumes the shape of a narrow stripe along those parts. And when it spreads in two directions, it makes a symmetrical triangular pattern along both sides of the dorsal median line, whose tip projects ventrally along the boundary between B.1 and B.2. It is very striking that the isolated dorsal pattern just over the whole extent of B.2 is found seldom, while the dorsal pattern often stretches longitudinally from B.1 to B.3 or to B.4 through B.2, and its ventral projection beyond Lsl occurs most frequently on B.2, sometimes along its boundaries or along Val and sometimes over the greater part of the abdominal bulge. The dorsal pattern on B.2 may be called the "back pattern".

The lateral pattern on the trunk is found on B.2. Its center seems to be at the point corresponding to the scales on Val or Vbl just on the line drawn between the anterior end of the dorsal fin to the base of the ventral fin. From this center it may extend to either of the two different directions. In one case it stretches ventrally along the line mentioned just above toward the base of the ventral fin, but its ventral end turns caudally and spreads rather widely along the ventral part of the abdominal bulge. In other cases it stretches caudally along Val and Vbl and spreads over the dorsal part of the abdominal bulge. The lateral pattern in both cases may be called the "flank pattern".

The ventral pattern is divided into three different parts. The cranial

part has its center on the base of the pectoral fin. At first it appears as a little dot on the ventral side of the base of the pectoral fin. Then it spreads caudally along the ventral median line near the base of the ventral fin. It stretches dorsally between the base of the pectoral fin and the margin of the gill-split. It forms a triangle on both sides of the ventral median line. This may be called the "pectoral pattern".

The middle part of the ventral pattern has its center on the base of the ventral fin. From this center it stretches caudad to the neighborhood of the anus along the ventral median line. Often it spreads dorsad over the abdominal bulge to Vcl or to Val. Its cranial margin is usually parallel to the gill-split, almost corresponding to Dvl 5, while its caudal margin runs along the caudal end of the abdominal bulge lying between Dvl 16 and Dvl 19. Along either side of the middle prominence of the abdominal bulge the pigmentation spreads easier than on the surface of the prominence itself. This middle part of the ventral pattern will be called the "abdominal pattern" in the narrow sense.

The caudal part of the ventral pattern has its center at the base of the anal fin. When it spreads over the base of the anal fin and projects dorsally along the furrow behind the abdominal bulge, it becomes a triangular pattern on either side of the ventral median line of the tail. This may be called the "anal pattern".

Fig. 28.

Pc Pigment center.
Op Opercular pattern.
Tp Tail pattern.
Pp Pectoral pattern.

Sp Snout pattern.
Np Neck pattern.
Tp Terminal pattern.
Abp Abdominal pattern.

Hp Head pattern.
Bp Back pattern.
Fp Flank pattern.
Ap Anal pattern.

5. Relation between the color pattern and the mode of connection of the skin to the substratum.

The spreading of the color pattern in the head seems to go on easily over the bone, but is more or less hindered by the sutures between bones. This may be attested in the following cases. The snout pattern extends only in the region where the skin is loosely connected to the bone in the snout. So also with the head pattern. Along its cranial margin the skin attaches tightly to the substratum and makes a distinct fold just behind it between the nares, preventing the further spreading of both the snout- and head-patterns beyond it. It spreads over the skull, and along its ventral margin, corresponding to that of both Pt and Fr, passes the stem of the lateral canal system. But the attachment of the skin to the substratum along this margin does not seem to make an absolute obstacle for the spreading of pattern beyond it. The head pattern can extend ventrally even along both sides of the eyes and the caudal margin of the opercula, where the skin attaches more loosely than the surroundings.

The opercular pattern is separated by the prominences on the middle of Sbb and Op. The dorsal opercular pattern is limited to the dorsal side of the prominence of Op, and the lateral one to the part between the prominences of Sbb and Op, and the ventral one to their ventral side. Each part spreads along that side of the prominences where the skin attaches rather loosely. The top of the prominences are usually not covered by the pattern, even when some of its parts are joined together.

The spreading of the color pattern in the trunk is generally influenced by the arrangement of the scales, showing the tendency to spread along the longitudinal scale line. This is also due to the difference of the grade of the attachment of the skin to the substratum and to the nature of the substratum (Figs. 28 and 29).

The dorsal pattern of the trunk is usually limited to the dorsal side of the lateral line, corresponding to the extension of the dorsal musculature. The ventral margin of the dorsal musculature in the goldfish does not agree with the lateral line, since the latter makes a line strongly bent ventrad and the former runs straightly on the scales on Dal. This is the very reason why the ventral margin of the dorsal pattern reaches sometimes Lsl and sometimes Dal. In either case, the limitation of the pattern is caused by the longitudinal connective tissue septum between

the dorsal and the ventral musculatures, which attaches to the skin along the lateral line, the lateral canal system itself having no direct relation to the distribution of the pattern. The dorsal pattern is sometimes

Fig. 29.

limited to the dorsal half of the back, and the scales along D.1 and D.3 are free from pigmentation. This may be due to the attachment of the second longitudinal connective tissue septum between D.1 and D.2 of the dorsal musculature (Nishi)¹⁾. This septum runs along the ventral margin of D.1 on B.1 and B.3, and across the scales of D.1 on B.2. This corresponds with the ventral margin of the dorsal pattern limited to the dorsal half of the back. In another case, the dorsal pattern appears merely as a thin stripe along the dorsal median line between the head and the dorsal fin or between the dorsal and caudal fins; sometimes extending along either side of the base of the dorsal fin. The extension of this pattern corresponds to the surface of each paired thin muscle stripes between the head and the dorsal fin and between the dorsal and caudal fins and also to the surface of the base of the dorsal fin, which are on the dorsal side of the longitudinal connective tissue septum along the dorsal margin of D.2. Thus the ventral extension of the dorsal pattern is generally restricted by the longitudinal connective tissue septa separating each of the dorsal musculature.

1) S. Nishi, *Folia Anatomica Japonica*. Bd. 1, 1923.

The limitation of the ventral pattern of the trunk corresponds to the extent of the longitudinal muscle band attaching to the bases of the fins on the ventral side of the body. The connective tissue septum along the dorsal margin of this muscle band agrees with the line drawn through the dorsal margin of the bases of those fins. The ventral pattern, however, often spreads even to Vcl or to Val over the abdominal bulge.

The limitation of isolated lateral pattern on the abdominal bulge is situated between the septum on the dorsal margin of the muscle band along the ventral median line, and the lateral line, the latter of which corresponds to the attachment of the septum between the dorsal and the ventral musculature.

The transverse separation of the color pattern of the trunk is made just along the lines, along which the skin makes folds or furrows when the fish moves forward. The most cranial of these folds runs between the cranial end of the dorsal fin and the base of the ventral fin, corresponding to Dvl 7 in the back and to Vp-Obl 6 in the abdomen. The middle fold runs between the caudal end of the dorsal fin and the base of the anal fin. It appears on the ventral side of the lateral line as the permanent distinct furrow along the caudal margin of the abdominal bulge. This furrow passes the lateral line over Ls 16-18, and the line continues rather cranio-dorsally across the back, ending at the point a little anterior to the caudal end of the dorsal fin. The caudal furrow-line agrees with the base of the caudal fin. These furrow-lines correspond exactly to the boundaries between the regions such as B.1, B.2, B.3 and B.4. The localization of the color pattern in these regions, therefore, means that the spreading is checked by the above folds or furrows.

The dorsal pattern in the trunk, which is bordered ventrally along the attachment to the skin of the septum between the dorsal and the ventral musculatures, may be divided into the neck-, the back-, the tail- and the terminal-patterns. These divisions owe to the furrow-lines along Dvl 7, along Dvl 16-19 and along the base of the caudal fin. The lateral pattern of the trunk, the flank pattern, is bordered dorsally along the lateral line, ventrally along the septum on the dorsal margin of the longitudinal muscle band of the fins on the abdominal side of the body, cranially along the prominence caused by the rib which comes from the fifth vertebra and caudally along the caudal end of the abdominal bulge.

The ventral pattern covers the area over the muscle band belonging to the fins on the ventral side of the body. The muscle band is separated

into three parts, each belonging independently to the different fin. So the pectoral pattern is limited to the area over the muscle belonging to the pectoral fin, the abdominal pattern to that of the muscle belonging to the ventral fin and the anal pattern to that of the muscle belonging to the anal fin.

The prominence on the middle of the abdominal bulge, like that on the operculum, strongly hinders the spreading of the color pattern. The flank pattern is forced to spread merely along the dorsal side or along the cranio-ventral side of this prominence, and both the dorsal and the ventral patterns produce their projections at first along the margins of the prominence.

The attachment of the skin to the substratum along the lateral line seems to make a strongest barrier for the spreading of the color pattern. Thus the dorsal pattern is usually limited to the dorsal side of the lateral line, while both the flank pattern and the dorsal extension of the ventral pattern over the abdominal bulge do not go beyond it. But the dorsal pattern can project to its ventral side along the above mentioned furrow-lines and the cranial margin of the trunk, which is also one of those lines. The flank pattern can stretch sometimes dorsally beyond the lateral line along the furrow-line between the cranial end of the dorsal fin and the base of the ventral fin and reach the base of the dorsal fin. Even the dorsal extension of the ventral pattern over the abdominal bulge shows the tendency to stretch dorsally beyond the lateral line along both sides of the bulge. In general, both the neck- and the tail-patterns are often produced isolated and they are most frequently limited to the dorsal side of the lateral line, though they sometimes project ventrally beyond the lateral line at its each end or along the furrow behind the abdominal bulge. On the contrary, the back pattern, which is usually produced with the neck pattern, makes very often a ventral projection beyond the lateral line along the furrow-line between the cranial end of the dorsal fin and the base of the ventral fin. And it accompanies also the tail pattern, and makes another ventral projection beyond the lateral line along the furrow-line between the caudal end of the dorsal fin and the base of the anal fin. But sometimes the back pattern extends ventrally beyond the lateral line through the whole length of the region B.2, limited to Val along the dorsal side of the prominence of the abdominal bulge or spreading beyond it to the neighborhood of the base of the ventral fin. The extent of the widest projection of the dorsal pattern over this part agrees exactly with that of the flank pattern, bordered cranially by Vp-Obl 6 corresponding to the attachment of the skin to

the rib of the fifth vertebra and caudally by the furrow behind the bulge which is made by the tight attachment of the skin to the underlying tissues. But the cranial margin of the ventral projection of the dorsal pattern is sometimes along Dp-Obl 5, more cranially than its usual limitation. This may mean the spreading cranially of the pattern beyond the attachment of the skin along the rib of the fifth vertebra, and yet it is limited again to the caudal side of another attachment of the skin along the rib of the fourth vertebra, corresponding to Vp-Obl 5.

On the contrary, the cranial margin of the dorsal projection of the ventral pattern over the abdominal bulge is not bordered by any ventro-caudal scale line like other patterns, and yet it makes the line almost parallel to the margin of the gill-split. Here any noticeable connection of the skin to the substratum does not exist along this line and also along the dorsal margin of Vcl, which frequently makes the limitation of the dorsal projection of the ventral pattern. So some other factor seems sometimes to play an important rôle in color spreading.

The pectoral pattern covers the region corresponding to the musculature of the shoulder girdle. Yet it is usually limited to the very part over the pericardial cavity, though it can project dorsally along the cranial margin of the trunk. The abdominal pattern may be limited to the surface of the musculature belonging to the ventral fin, but often spreads dorsally to the flank. This dorsal extension is not limited to the region between both furrow-lines, on which the flank pattern and the ventral projection of the back pattern are produced. Its cranial margin corresponds to that of the peritoneal cavity underneath, and when the pattern is limited to the ventral side of the line between Vbl and Vcl, this dorsal margin agrees with that of the peritoneal cavity. The dorsal spreading of the abdominal pattern to the lateral line means its covering the whole surface of the abdominal cavity including the peritoneal cavity and the retroperitoneal organs, the gonad, the air-bladder and the kidney. The anal pattern spreads on the region corresponding to the extent of the base of the anal fin, so that it is limited to the ventral side of the tail. This strengthens the above statement that the definite localization of the color pattern is not always controlled by the tight attachment of the skin to the substratum, but it is affected by the different internal condition at various regions.

6. Actual course of the spreading of pigmentation in the skin.

In my previous paper it is ascertained that the distribution of the color pattern of the goldfish agrees well with that of the temporary black

pattern, which appears on the black ones after adrenalin injection. The pattern is caused by the difference in the degree of the contraction of the melanophores in different parts. As adrenalin acts upon the sympathetic nervous system, the paler parts after adrenalin injection seems to be produced by an insufficient supply of this chemical. Moreover it is noteworthy that the formation of temporary black pattern takes the same sequence as that of the pigmentation in the adult fishes and the process of the depigmentation occurring physiologically in the young. The latter process often stops short, thus causing various color patterns in the adult.

It is interesting to state that the pigmentation in the skin of the goldfish has the tendency to remain or to appear most frequently at the parts where the blood- or lymph-stream is strongly obstructed. Indeed, both the natural pattern and newly produced pigmentation are usually limited to the peripheral ends of the body such as the margin of the fins, the snout and the opercula, where the obstruction seems strong. This agrees well with the general phenomenon of the so-called "Spitzen-pigment" of other vertebrates. Persistent retention of the color pattern along the dorsal median line corresponds to the so-called "Aalstrich," the dorsal pigmentation found in other forms.

The pigmentation of the goldfish increases at low season temperature and decreases at high season temperature, so that the dorsal pigmentation has nothing to do with the heat rays received from the sun. As to the process of depigmentation of the young goldfish Koketsu¹⁾ states that the melanin granules produced by the disintegrated melanophores are captured by the phagocytes and most of them are carried into the inner lymphatic tissue through the lymph vessels. According to Weidenreich²⁾ the pigmentation of cold-blooded animals is generally localized in the lymphatic tissue of the perineural, perivascular, subperitoneal and subcutaneous regions. The opinion expressed by these authors may support that the color pattern and the lymph system are closely related.

The tight attachment of the skin to the underlying tissue may hinder the lymph passage in the subcutaneous tissue, and this in turn may become a barrier against the spreading of color pattern. In using methylen-blue or carmin solution the mode of spreading in the skin was examined. When it was injected cranial in the subcutaneous tissue behind the dorsal fin, it first spread along the base of the dorsal fin, but it did not

1) R. Koketsu, *Dobutsugaku Zasshi*, Bd. 27, 1915. (Japanese)

2) F. Weidenreich, *Zeitschr. f. Morph. u. Anthropol.* Bd. 15. 1912.

go beyond the boundary between B.2 and B.3. It then turned ventrally along the furrow behind the abdominal bulge and at last reached the base of the anal fin. Irrespective of the quantity of solution and of the degree of pressure the solution injected in the tail did not spread outside of the tail. In a few cases when it was injected rather deeply cranial from behind the dorsal fin, the solution ran straightly along the whole length of the base of the dorsal fin. This seems to be due to the penetration of the tip of the injection-needle into B.2 through the cranial boundary of B.3. The solution injected subcutaneously somewhere on B.2 of the back remained usually within the same region, though sometimes it extended ventrally to Vb1 beyond the lateral line. And when the solution was injected subcutaneously somewhere on B.1 of the back, it remained within the same region. The solution injected in the snout remained in the same part. The solution injected in any region of the dorsal side of the head spread widely over it except the snout and the ventral part of both Sbb and of the opercula. Thus the color solution injected subcutaneously on the dorsal side of the body is usually restricted to the regions in which the injection was made, the regions of the dorsal patterns. On the contrary the solution injected in the peritoneal cavity did not appear in any part, where the dorsal pattern might be produced, though it exuded out more or less into the skin of the abdominal bulge.

The pigmentation newly produced after repeated injections of adrenalin into white and variegated goldfishes spread similar to the color solution. As was described in my previous paper¹⁾, when the subcutaneous injection of adrenalin was repeatedly made into the back, pigmentation always occurred in the distribution similar to that of the ordinary dorsal pattern, and when intraperitoneal injection was repeated, the pigmentation was limited to the same area as the lateral and the ventral patterns. It may be added that the pigmentation was not caused by the adrenalin solution carried in the blood, because it first appears around the point of injection and then spreads in the same direction as the needle was directed.

From these facts it is clear that the distribution of pigmentation in the skin of the goldfish is controlled by the special condition of the lymph passage in the subcutaneous tissue, and it can be stated that in general pigmentation first appears on the peripheral parts of the body, where the retention of the lymph fluid in the skin is likely to take place

1) K. Fukui, *Folia Anatomica Japonica*. Bd. V. 1927.

more readily, and spreads gradually to the surrounding parts always along the loose subcutaneous tissue, while its spreading is more or less hindered by the close attachment of the skin to the underlying tissue. If so, depigmentation should occur in the part where the pigment is readily carried away by lymph-circulation and should stay longer in the part where the lymph is likely to be retained. This actually happens in the young goldfishes in which the process of the depigmentation takes the course exactly reverse to the color spreading.

An interesting case may here be added. I injected several times a large quantity of physiological saline solution into the left side of the back of a black-backed goldfish. This made its left flank very oedematous, and pigment formation ensued there, no pigment appearing on the right side.

7. Summary.

1. The mode of spreading of pigment of the goldfish is similar both in the black and in the red patterns. According to their distribution they can be divided into the dorsal, lateral and ventral patterns.

2. The dorsal pattern of the head is separated into two parts. The snout pattern spreads from its center on the jaw, but is restricted to the snout. The head pattern spreads from its center on the point where the dorsal median line and the boundary between the head and the back cross each other. In its various extension it is always restricted by the junction of bones of the skull underneath. The largest one covers the whole surface of the skull.

3. The dorsal pattern of the trunk is usually limited to the dorsal side of the lateral line, and is separated into four definite parts. The neck pattern spreads caudally from the same center as the head pattern and covers the anterior part of the back anterior to Dvl 7. The back pattern accompanies usually the neck pattern. Its center lies before the anterior end of the base of the dorsal fin and it covers the middle part of the back between Dvl 7 and Dvl 16-19. The tail pattern has its center behind the posterior end of the base of the dorsal fin and spreads over the posterior part of the back posterior to Dvl 16-19. The terminal pattern is produced on the dorsal margin of the base of the caudal fin. The terminal pattern sometimes accompanies the tail pattern and sometimes does not. The extension of each dorsal pattern very often corresponds to the arrangement of each part of the dorsal musculature such as D.1, D.2 and D.3.

4. The lateral pattern in the head is limited to the opercular pattern.

It is divided into three parts. The dorsal one is restricted to Sop, the lateral one being on either side of the junction between Op and Sbb, while the ventral one stretches along the ventral part of both operculum and Sbb. The lateral pattern in the trunk is limited to the flank pattern. Its center lies at the point where Vp-Obl 7 and Val or Vbl cross each other. It spreads over the abdominal bulge, being limited cranially by Vp-Obl 6, caudally by the furrow behind the abdominal bulge, dorsally by the lateral line and ventrally by the line drawn through the bases of three fins along the ventral median line.

5. The ventral pattern is limited to the trunk and consists of three different parts. The pectoral pattern has its center on the base of the pectoral fin and is limited to the surface of the pericardial cavity. The abdominal pattern has its center on the base of the ventral fin and is limited to the surface of the musculature belonging to the same fin. In its dorsal extension it covers the abdominal bulge corresponding to the surface either of the peritoneal cavity or of both the peritoneal cavity and the retroperitoneal organs. The anal pattern has its center on the base of the anal fin and spreads over the surface of the furrow behind the abdominal bulge.

6. Thus each color pattern of the goldfish has its own center and spreads to a certain restricted areas of the body. The spreading takes place always along the parts of loose subcutaneous tissues and is prevented by the close attachment of the skin to the substratum.

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