ON THE SPECIFICITY OF KIDNEY CATALASE ACTIVITY IN SALMONID FISHES

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Many investigators have been of the opinion that some biochemical changes all combine to change the tissues of the freshwater salmon parr toward the marine salmon at the time of smolt transformation, to modify in turn the internal environment, and perhaps to force the fish to migrate under a correlation with cyclical changes in the external environment.[1)–9)]

It is easily understood that mucous or silvering coat, gill, oral membrane and kidney are important as the functional sites of osmoregulation when fishes are transferred from freshwater to sea water or *vice versa*.[3) 10)] The finding of the chloride cells in both the gill and inner surface of the operculum is very important in this connection.[2) 3) 11)–14)] However, as Black[3)] has stated, there has been no marked evidence presented to prove that the ability of fish to adapt to sea water is dependent for the most part on the chloride cells. It seems to be probable that diadromous or euryhaline fishes might maintain osmotic homeostasis in sea water not only by means of the chloride cells, but also by some specific characteristics of the kidney. In this connection, the finding on the existence of the kidney phosphatase in some marine fishes is very suggestive.[15)]

Morphologically, the kidney of the salmonid fishes has been classified from the glomerular structure into the same group with that of the typical freshwater fishes.[16) 17)] However, Grafflin[18)] has concluded that there is no correlation between the structure of the kidney and potentiality to adapt to fresh or to sea water. Possibly, biochemical studies on the kidney may give some answers to Grafflin's conclusion.

Having such a purpose in mind, the present authors undertook the below-described preliminary experiment to find some specific characteristics of the kidney catalase activity in the salmonid fishes, sweetfish and lamprey, also those of some typical freshwater and marine fishes.

Although the physiological role of the catalase is still a matter for discussion,[19)] it has been clarified that the catalase has not only a function of dissolving hydrogen peroxide which is toxic to living cells, but also that it has an oxidatic function in living cells or organisms, and that it has a close resemblance in spectral structures to horseradish peroxidase, cytochrome and hemoglobin.[19)–21)]

The authors are indebted to the following persons who aided in supplying the materials used: staff members of the Hokkaido Fish Hatchery, staff members of the

Ueda Branch of the Freshwater Fisheries Research Laboratory, the members of the Fisheries Association of Kamiiso, Hokkaido, Messrs. T. Kubo and W. Otomo of Hokkaido University, and Mr. T. Ishii. Thanks are likewise offered to Prof. W. S. Hoar of the University of British Columbia for his kind sending of literature. Thanks are also due to Mr. H. Fukuda of Miyazaki University for his helpful suggestions regarding the measurement of the tissue catalase activity. The authors wish to acknowledge their indebtedness to Prof. S. Sato and Mr. T. Ueno of Hokkaido University for kindly identifying the species of the fishes used.

MATERIALS AND METHODS

Fishes. Various kinds of records of the fishes used in the present experiment are summarized in Table 1. Most of these fishes were transported from the localities where they had been collected, into the laboratory by preserving them in a portable ice-box. They were dissected, at least within 24 hours, to obtain the tissues to be tested. Only in the case of the crucian carp, they were sacrificed after being fed sparingly one or two days in a laboratory tank with dried and ground crustacean larvae. Both male and female fishes were used, since no differences of the tissue catalase activities were detectable between the sexes, though the number of individuals examined were only a few in most of the species.

Blood sampling. The blood catalase activity of only 3 species was examined. In all cases, the blood was collected from caudal vessels.[22] To prevent blood coagulation, the blood drops were collected in a small vessel, the inner wall of which has been previously filmed with dried powder of the appropriate volume of 0.2%

Table 1. Records of the fishes used in this experiment

No.	Species (Common name)	Date of sampling	Body		Habi-tat*
			Weight g	Standard length mm	
	Salmonidae				
1a	***Oncorhyuchus keta,*** fry (Chum salmon)	Aug. 11	3–5	64–74	F
1b	ditto, underyearling	Dec. 8 & 21	6–28	85–143	F
1c	ditto, adult mature	Nov. 26	2600–5000	620–760	F
2	***O. nerka*** (Landlocked red salmon)	Aug. 11	121	213	F
3a	***O. masou,*** smolt (Masu)	June 30	18–31	117–144	F
3b	ditto, parr	July 9	23–73	107–166	F
4	***Salmo irideus*** (Rainbow trout)	Aug. 3	22–42	110–140	F
5	***Salvelinus malma*** (Dolly vorden trout)	Nov. 26	130, 165	200, 235	F
6	***S. fontinalis*** (Brook trout)	ditto	127–460	218–323	F
7	***S. leucomaenis pluvius*** (Mountain trout)	ditto	50–285	150–280	F
	Plecoglossidae				
8a	***Plecoglossus altivelis*** (Sweetfish)	Aug. 19	50–57	145–155	F
8b	ditto	Aug. 23	15–26	107–125	F
8c	ditto	Aug. 26	33–42	137–148	F

	Cyprinidae				
9	***Hemibarbus barbus*** (Barbel)	Oct. 8	41–112	136–161	F
10	***Pseudogobio esocinus*** (False goby minnow)	ditto	9–44	104–166	F
11	***Pseudorasbora pumila*** (a species of minnow)	Oct. 10	3–8	58–75	F
12	***Zacco platypus*** (a species of minnow)	Oct. 8	11–27	87–120	F
13a	***Tribolodon hakuensis hakuensis*** (Common dace)	July 16	4–46	64–146	M
13b	ditto	Aug. 11	101, 167	184, 209	F
14	***Carassius auratus*** (Crucian carp)	May 26–27	22–89	96–152	F
15	***Cyprinus carpio*** (Carp)	Oct. 1	128–187	170–200	F
16	Siluridae				
	Parasilurus asotus (Sheatfish)	Oct. 9	103, 106	263, 265	F
17	Cobitidae				
	Misgurnus anguillicaudatus (Loach)	Sept. 10	7–12	105–126	F
18a	Anguillidae				
	Anguilla japonica, cultured (Eel)	Sept. 30	119–221	460–530	F
18b	ditto, river	Oct. 9	149–635	530–750	F
19	Cottidae				
	Cottus pollux (Sculpin)	ditto	15, 28	122, 130	F
	Osmeridae				
20	***Hypomesus olidus*** (Pond smelt)	Oct. 24	2–4	54–72	F
21	***H. japonicus*** (Surf smelt)	Dec. 17	10–17	107–130	M
	Engraulidae				
22	***Engraulis japonicus*** (Anchovy)	Dec. 3	11–32	110–140	M
23	Aulorhynchidae				
	Aulichthys japonicus (Cornet fish)	July 16	2, 3	103, 115	M
24	Hemirhamphidae				
	Hemirhamphus sajori (Half beak)	Dec. 3	24	206	M
	Carangidae				
25	***Tarachurus japonicus*** (Horse mackerel)	ditto	4–7	60–72	M
	Tetraodontidae				
26	***Sphaeroides borealis*** (a species of puffer)	ditto	44–93	110–140	M
27	***S. stictonotus*** (Spotted puffer)	ditto	29	95	M
28a	Hexagrammidae				
	Hexagrammos otakii (Green ling)	ditto	28	115	M
28b	ditto	July 16	15	94	M
29	Ammodytidae				
	Ammodytes personatus (Sand lance)	Dec. 3	32–39	183–198	M
30	Blenniidae				
	Opithocentrus ocellatus (a species of blenny)	July 16	3–32	62–126	M
31	***O. zonope*** (a species of blenny)	ditto	7	92	M
32	Pleuronectidae				
	Cleisthenes herzensteini (a species of flounder)	Dec. 17	78–106	185–200	M
33	***Microstomus achne*** (a species of flounder)	March 3	86–135	175–202	M
	Sphyraenidae				
34	***Sphyraena japonica*** (Barracuda)	Dec. 14	41	179	M
	Petromyzontidae				
35	***Lampetra japonica*** (Lamprey)	Dec. 4	156–220	450–520	F

* Habitat. F : Freshwater. M : Marine.

sodium oxalate solution. Using a melangér, the blood was diluted, in most cases, into 500 times by M / 7.5 NaCl. Thus, the blood catalase activity was measured on the erythrocyte suspension prepared in such a manner. Just as in the blood of man and rabbit,[23] no reduction of the activity was found in the crucian carp, at least for 36 hours, when the suspension had been preserved in ice-box.

Tissue sampling. In most of the species, only the liver and kidney were removed

from each fish. In 9 species, liver (or hepatopancreas), kidney, gill, stomach (or anterior intestine) and white skeletal muscle were sampled. In some small fishes, such as chum salmon fry, 2 to 4 tissues were combined, as a single tissue was too small to make an enzyme solution. For instance, the total wet weight of 2 kidneys of the chum fry was hardly 0.06–0.08 g. In case of the liver and kidney, generally the whole tissue was sampled respectively, except for the special case of a large fish, such as a mature adult salmon, in which case a small cut of each tissue was removed. Gills were cut off from one side of each fish. After both scales and skin had been flayed, white skeletal muscle was cut off in an appropriate mass, from the constant portion of the body, such as just ventral to the anterior part of the dorsal fin.

Enzyme preparation. In all cases, each of the chilled tissues was finely ground within a mortar or homogenated by a glass homogenizer, without the addition of any kind of abrasives, and then, diluted into 100–3000 times of the tissue wet weight g, by adding the required volume of M/7.5 NaCl. After being filtrated through the 4 sheets of gauze to remove gross particles, it was preserved for about 2 hours, in an ice-box to extract the tissue enzyme. From the preliminary experiments for finding the optimum degree of the dilution of the tissue, it was ascertained that dense concentration of the enzyme solution is not desirable for the permanganate titration, possibly due to side reactions between permanganate and impurities.[19] Further, it was found that a tissue having high catalase activity such as liver and kidney must be diluted into a suitable degree, at least, under the conditions of the

Table 2. (a) Relation between catalase activity and rate of dilution in liver

Rate of dilution	*Salmo irideus***				*Microstomus achne*			
	No. 1		No. 2		No. 1		No. 2	
	k	CA*	k	CA	k	CA	k	CA
250	0.1366	34	0.1570	39	0.1606	40	0.1603	40
500	0.1314	66	0.1515	76	0.1440	72	0.1400	70
750	0.1092	82	0.1116	84	0.0935	70	0.0887	67
1000	0.0989	99	0.0991	99	0.0619	62	0.0630	63
1500	0.0373	56	0.0406	61	0.0378	57	0.0384	58
2000	0.0284	57	0.0298	60	0.0278	56	0.0281	56
3000	0.0176	53	0.0199	60	0.0170	51	0.0157	47

(b) Relation between catalase activity and rate of dilution in kidney

250	0.0498	12	0.0853	21	0.1125	28	0.1099	27
500	0.0278	14	0.0289	14	0.0549	27	0.0464	23
750	0.0199	15	0.0195	15	0.0325	24	0.0282	21
1000	0.0133	13	0.0116	12	0.0242	24	0.0210	21
1500	0.0081	12	0.0087	13	0.0143	21	0.0120	18

* CA, catalase activity; ** date of experiment, March 17.

present estimation. As indicated in Table 2, when dilution of the tissue was made to be in the range of about $0.020 < k < 0.040$*, the catalase activity was desirably measured, for the first time, to be approximately constant. Otherwise, the activity is measured to be either too high or too low, comparing with its proper value. However, as the catalase activities of the gill, stomach and white skeletal muscle are highly variable, these tissues were diluted uniformly to 100 times. So, the catalase activities of these tissues as presented in this paper may be, in most cases, a little lower than their proper values.

Estimation and calculation of the tissue catalase activity. The present method of the estimation was established for obtaining only the relative values of catalase activity in every tissue among the species. One ml of the tissue enzyme solution was allowed to react with 5 ml of 0.04 N H_2O_2 at 20°C, the reaction being stopped after 10 minutes by the addition of 2 ml of 10 % H_2SO_4. The H_2O_2 remaining was estimated by titration with 0.01 N $KMnO_4$. To prepare 0.04 N H_2O_2, M/15 phosphate buffer solution (pH 6.9) of Sörensen was used, and NaCl was added up to 0.5 %. The catalase activity presented in this paper was calculated in k per dilution rate of tissue wet weight g (*cf.* Table 2), except that of the blood, where it was calculated in k per dilution rate of the blood volume sampled.

RESULTS

The catalase activities of the liver and kidney were measured in 35 species belonging to 19 families, including both freshwater and marine fishes; those of the gill, stomach, skeletal muscle and blood were also estimated in several species. The results are shown in Tables 3 and 4. Although the species examined are few in number, the catalase activities of these tissues are arranged approximately in the following order: liver > kidney > blood > gill > stomach > skeletal muscle.

The specificity of the kidney catalase activity in the salmonid fishes, sweetfish and lamprey

The catalase activities of the kidneys are given in Table 3, together with those of the livers. As is clearly seen in this table, the kidney catalase activities in all of the salmonid fishes, sweetfish (No. 8) and lamprey (No. 35) are much higher than those in the typical freshwater fishes (No's. 9–19, except No. 13). It is noteworthy that both the sweetfish and lamprey are also diadromous fishes like some of the salmonid species examined. In all of the salmonid fishes, this specificity was commonly found regardless of the stage of development, or whether they were landlocked forms, parr or smolt.

Among the diadromous fishes examined, however, three exceptions were found, *viz.*, common dace (No. 13), pond smelt (No. 20) and eel (No. 18). As to the first

* $k = 1/t \cdot \log X_0/X$; the extrapolation for $t \to 0$ was not made.

species, both the marine (a) and freshwater (b) forms were collected and examined. The kidney catalase activities of both forms are equally low, being the same as those of the typical freshwater fishes. The second species showed also a low catalase activity in the kidney. The individuals used were all landlocked form and very small in body size, as indicated in Table 1. It is not clear at present whether the observed low activity resulted from the very small size of the kidney or it was a proper value of this species. If the latter is the case, the clear difference of the kidney catalase activity between this species and surf smelt (No. 21) may become a basis for the systematic confusion of these two species.[24] The kidney catalase activity of the third species (the eel) is extremely low, both cultured and river forms showing an equal level.

In all of the typical freshwater fishes, the catalase activity of the kidney was

Table 3. Catalase activities of the liver and kidney in fish

No.	Species	No. of fishes	Catalase activity M ± σ	
			Liver	Kidney
1a	*Oncorhynchus keta*, fry	6(1)	89 ± 4	9.8 ± 1.4
1b	ditto, underyearling	11(4)	75 ± 11	23 ± 3
1c	ditto, mature adult	5	87 ± 11	12 ± 2
2	*O. nerka*	1	59	11
3a	*O. masou*, smolt	8	58 ± 5	18 ± 2
3b	ditto, parr	10	64 ± 7	18 ± 4
4	*Salmo irideus*	10	74 ± 16	19 ± 3
5	*Salvelinus malma*	2	69, 94	12, 26
6	*S. fontinalis*	8	86 ± 11	22 ± 4
7	*S. leucomaenis pluvius*	4	86 ± 10	25 ± 3
8a	*Plecoglossus altivelis*	4	67 ± 10	11 ± 2
8b	ditto	4	57 ± 6	11 ± 2
8c	ditto	5	55 ± 8	16 ± 3
9	*Hemibarbus barbus*	4	63 ± 9	1.1 ± 0.2
10	*Pseudogobio esocinus*	4	41 ± 10	1.6 ± 0.6
11	*Pseudorasbora pumila*	12 2)	67 ± 13	4.6 ± 1.7
12	*Zacco platypus*	4	69 ± 22	2.5 ± 0.7
13a	*Tribolodon hakuensis hakuensis*	15	79 ± 16	3.1 ± 1.3
13b	ditto	2	91, 99	2.6, 3.4
14	*Carassius auratus*	5	46 ± 15	2.2 ± 0.4
15	*Cyprinus carpio*	6	97 ± 10	4.1 ± 0.5
16	*Parasilurus asotus*	2	40, 48	2.2, 2.7
17	*Misgurnus anguillicaudatus*	6(1)	49 ± 6	3.8 ± 1.1
18a	*Anguilla japonica*, cultured	8	80 ± 12	0.63± 0.22
18b	ditto, river	3	61 ± 9	0.69± 0.42
19	*Cottus pollux*	2	32, 52	2.1, 3.4

20	*Hypomesus olidus*	23[3]	64 ± 8	3.5 ± 0.8
21	*H. japonicus*	16[1]	64 ± 9	17 ± 3
22	*Engraulis japonicus*	8	81 ± 8	4.2 ± 1.0
23	*Aulichthys japonicus*	2	13, 21	0.32, 0.40
24	*Hemirhamphus sajori*	4	94 ± 13	4.7 ± 1.8
25	*Trachurus japonicus*	4	81 ± 9	3.1 ± 1.0
26	*Sphaeriodes borealis*	10	16 ± 6	5.9 ± 1.6
27	*S. stictonotus*	5	14 ± 3	4.7 ± 2.0
28a	*Hexagrammos otakii*	6	58 ± 8	18 ± 3
28b	ditto	1	47	17
29	*Ammodytes personatus*	8	88 ± 11	4.8 ± 2.1
30	*Opithocentrus ocellatus*	3	57 ± 8	4.1 ± 1.3
31	*O. zonope*	1	8.0	0.32
32	*Cleisthenes herzensteini*	5	58 ± 9	14 ± 4
33	*Microstomus achne*	4	61 ± 6	20 ± 4
34	*Sphyraena japonica*	1	79	9.0
35	*Lampetra japonica*	5	75 ± 10	23 ± 6

(1) two, (2) three, and (3) seven or eight tissues were combined all to test; (4) two tissues for smaller individuals only.

found to be uniformly low. Such a characteristic appears to be common to this group.

Although the kidney catalase activities of the marine fishes (No's. 22-34) appear to be widely variable, those are distinctly classified into the two types, similar to the types of the typical freshwater and salmonid fishes. If many more species of the marine fishes are examined, such a tendency may become more distinct. Similarly to the smelt above described, two species of the blenny belonging to the same genus (No's. 30 & 31) showed a clear difference of kidney catalase activity.

Catalase activities in various kinds of tissues in fishes

As indicated in Tables 3 and 4, except the blood, the catalase activities of tissues of the gill, stomach and skeletal muscle are much lower than those of the liver and kidney.

Liver. In the majority of the examined fishes, the liver catalase activities range from about 40 to 100. While, in some of the marine fishes, such as cornet fish (No. 23), puffer (No's. 26 & 27) and blenny (No. 31), very low activities were found, ranging from only about 10 to 20. Thus, the two types were also distinctly distinguishable in the activity of this tissue.

Gill, stomach, muscle and blood. The catalase activities of these tissues are low, and show a wide variation respectively. The gill catalase activities of the salmonid fishes appear to be higher than those of the others. However, further studies are necessary to determine exactly such a point. As in the case of the kidney, the

Table 4. Catalase activities of the gill, stomach, muscle and blood in fish

No.	Species	No. of fishes	Catalase activity M ± σ			
			Gill	Stomach	Muscle	Blood
1a	*Oncorhynchus keta*, fry	6(1)	1.18±0.46	0.71±0.05	0.19±0.04	——
1b	ditto, underyearling	11(4)	2.84±0.68	1.59±0.43	0.28±0.10	——
2	*O. nerka*	1	1.29	0.52	0.14	——
3a	*O. masou*, smolt	8	1.94±0.44	1.18±0.31	0.34±0.24	14 ± 3
3b	ditto, parr	10	2.27±1.61	0.93±0.29	0.20±0.13	13 ± 2
4	*Salmo irideus*	10	2.38±1.68	1.02±0.50	0.58±0.40	13 ± 2
8a	*Plecoglossus altivelis*	4	1.37±0.20	1.05±0.21	0.47±0.35	——
8b	ditto	4	2.40±1.41	3.94±1.38	0.12±0.02	——
13b	*Tribolodon hakuensis hakuensis*	2	0.88	0.85	0.19	——
14	*Carassius auratus*	5	0.50±0.18	0.47±0.17	0.11±0.04	2.9± 0.8
17	*Misgurnus anguillicaudatus*	6(1)	1.61±0.30	1.25±0.05	0.16±0.04	——
18a	*Anguilla japonica*, cultured	8	0.48±0.10	0.70±0.24	0.14±0.03	——

(1) & (4), see Table 3.

catalase activity of the gill of the eel is much lower than that of the other fish. The blood catalase activities of the salmonid fishes are, at least, much higher than that of the crucian carp. Regarding the stomach and muscle, no specific characteristics in the catalase activities were detectable. However, that may be due to the unsuitable method of the estimation for these tissues having very low catalase activities.

DISCUSSION

The physiological role of the catalase is still a matter of discussion. However, in addition to the protection of cells from toxic destruction by hydrogen peroxide, its oxidatic function in cells or organisms has been clarified though yet only in outline.[19)-21)] The physiological significance of the tissue catalase also poses a problem that must be studied in the future since they are of much interest.[19)] Consequently, no detailed discussion can here be offered on the physiological significance of the specificity of the kidney catalase activity found in the salmonid fishes and some others, only it may be presumable that some active oxidatic reactions do occur in such a tissue.

It is well known that in most of the animals the tissue catalase activities show the highest value in liver,[19)25)-27)] as was also observed in the present experiment. If this fact offers evidence of some active oxidatic reactions in liver, the same idea may be also applicable to the kidney. That is to say, it may be judged that if the catalase activity of a kidney is comparatively high, the biochemical reactions in the kidney are more active.

In view of the diadromous migrations of the sweetfish and lamprey,[28)] it seems

to be a significant fact that the kidney catalase activities of these fishes are both very high like those of the salmonid fishes. Further, it is noticeable that high activities of the blood lipase have been reported in both of the lamprey and salmon.[9]

If the glomerulus of fish functions like that of mammals, no supply of energy is necessary for its filtration, while much energy might be consumed for salt absorption or excretion in the renal tubules.[29][30] Marine fishes swallow sea water with its contained salts to prevent the loss of body water.[3][16][31]-[33] Consequently, they must eliminate the unwanted salts in some way as rapidly as possible. In most of the marine fishes, the glomerulus has become vestigial.[3][16][17][34] So, in these fishes the renal tubules might accomplish a large part of the salt excretion. It is presumable that very much energy may be consumed by the performance of this function. The same assumption may be applicable to the osmoregulation of diadromous fishes; or, even much more energy may be necessary for these fishes than the marine ones, in adapting to a new environment. In fact, Grafflin[18] has reported that there is no correlation between the structure of the kidney and the ability to adapt to fresh or sea water. Further, Marshall and Grafflin[30] have found an important fact that the active excretion of both organic and inorganic substances is detected in the renal tubules of some marine fishes, against the higher pressure of the ureter.

Possibly, fishes about to migrate from freshwater to sea water might also have previously some physiological and biochemical potentialities capable of maintaining osmotic homeostasis in a new environment. The existence of such potentialities has been repeatedly proved in the biochemical changes of the blood and liver, and in the chloride cells.[1]-[4][13][14] Besides these evidences, changes of the hormonal activities might be also associated with the osmoregulation in fish.[2]-[4][8][35]

However, viewing osmoregulation from the biochemical standpoint, there have been very few findings on the specificity of the kidney in diadromous or euryhaline fishes. In that respect, it may be said that the finding of the existence of the kidney phosphatase in some glomerular and aglomerular fishes has been a stimulating suggestion in this field.[15] The specificity showing a high activity of the kidney catalase seems to suggest also the existence of a high potentiality of osmoregulation in fish. To establish such an assumption, however, it must be substantiated whether catalase and other enzymes of the fish kidney are closely related with the physiological roles of this tissue in conncection with the osmotic homeostasis or not. Further, it must also be clarified why the salmonid fishes including the landlocked forms, parrs and smolts show commonly a high catalase activity in the kidney. For the marine fishes, the reasons for the existence of the two types of kidney catalase activity are obscure.

The kidney catalase activity of the eel was found to be very low. It is noteworthy that this fact agrees with the scantiness of kidney phosphatase in this fish.[15] If

the specificity of the kidney catalase activity is actually associated with the osmoregulation in fish, it is presumable that the osmoregulation of the eel might possibly be porformed by some mechanism different, at least, from that of the salmonid fishes, sweetfish and lamprey.

However, practically it can only be said here that the kidney catalase activity of the salmonid fishes, sweetfish, lamprey and some of the marine fishes is much higher than that of the typical freshwater fishes, and that, on the contrary, that of the eel is extremely low, even in comparison with the latter group.

SUMMARY

To detect some specific characteristics of the kidney in diadromous fishes, the catalase activity of kidney tissue was measured on the salmonid fishes, sweetfish, lamprey, eel and some others, and compared with that of the typical freshwater and marine fishes. Besides the kidney, the catalase activities of tissues of the liver, gill, stomach, white skeletal muscle and of the blood were estimated.

1. Although it is not possible to discuss in detail the results obtained as the physiological significance of the tissue catalase is not clear at present, it was clarified that the kidney catalase activities of the salmonid fishes, sweetfish, lamprey and some of the marine fishes are much higher than those of the typical freshwater fishes, while that of the eel is extremely low, even comparing with the latter group.

2. Except the eel, the kidney catalase activities of the typical freshwater fishes are low, showing no marked differences among the species. Those of the marine fishes appear to be highly variable, but they are distinctly classified into two types, just as similar to the types of the typical freshwater and salmonid fishes above described.

3. On the liver catalase activities, similarly the two types, high and low, were distinctly discriminated. Generally, those of the marine fishes are widely variable, and the low type of activity was found only in some of this group.

4. The gill catalase activities of the salmonid fishes appear to be higher than those of the other fishes, while that of the eel gill is much lower, like the kidney. The blood catalase activities of the salmonid fishes are, at least, much higher than that of the crucian carp.

5. From the view point of the osmoregulation in fish, some assumptions were offered on the high catalase activity in the kidney of the diadromous fishes.

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