VITAMIN CONTENTS IN THE LAMPREY, *ENTOSPHEENUS JAPONICUS* MARTENS

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In Japan the lamprey, *Entosphenus japonicus* Martens, has often been recommended since old times as a diet efficacious for curing night blindness and tuberculosis because of its rich source of nourishment. Fujimaki (1), Miura (2) and Nakamiya (3), reported the nutritive factors in the lamprey on different occasions and maintained that the vitamin A content of its flesh is several times as much as that of fresh butter or oil of the eel.

Based on the works carried out by the authors in regard to the biochemical significance and variability of vitamin A in fish of different species, it can be said that the lamprey is a very unusual fish in various vitaminological aspects. The present paper deals with the results of the experiments conducted with the samples caught in the Mogami River, Yamagata Prefecture, in various seasons during 1951 to 1956.

FIG. 1 *External Appearance of the Lamprey*

The lamprey (Fig. 1) are caught in rivers flowing into the Japan Sea. In autumn mature lampreys come up in large groups from the sea to the rivers for spawning. As their gonads mature during a few months, usually from April to May, of freshwater life, they spawn in the upper streams.

The hatched larvae descend the river into the sea and grow up to maturity. As yet, it remains quite unsettled how many years they stay in the sea, though they are believed to remain at the bottom of the sea for about seven years. In fishing districts the lamprey caught are kept for several days in a small cage without food until being shipped to market.

EXPERIMENTAL

Methods and Materials

Vitamin A was determined by estimating the optical density at absorption

maximum, 325 m μ , of the unsaponifiable matter of the oil. The results were subjected to the Morton-Stubbs' correction. For the samples in which no correction was made because of some difficulties, a colorimetric method with

TABLE I
Vitamin A Content in Various Parts of Lamprey

Sample number	Sex	Body length	Body weight	Flesh			Liver				Sexual organ				Iodine number of body oil
				Oil content	Vitamin A in oil	Vitamin A in tissue	Weight	Oil content	Vitamin A in oil	Vitamin A in tissue	Weight	Oil content	Vitamin A in oil	Vitamin A in tissue	
		cm	g	per cent	I.U./g	I.U./g	g	per cent	I.U./g	I.U./g	g	per cent	I.U./g	I.U./g	
1	♀	47.6	205	16.0	3,900	625	4.5	2.7	169,000	4,570	32	12.2	1,590	194	129
2	♀	46.6	204	10.1	2,125	215	5.8	2.2	72,200	1,550	41	11.1	1,630	181	111
3	♀	45.7	186	16.1	1,840	297	5.8	2.3	59,000	1,345	44	11.3	895	99	128
4	♀	49.2	202	20.0	1,440	288	4.8	4.4	71,200	3,135	20	13.5	1,200	162	125
5	♀	43.8	141	15.5	5,170	802	4.8	3.5	200,000	7,080	12	12.8	3,320	425	132
6	♀	45.1	132	5.5	1,800	99	4.8	5.3	92,700	5,010	14	13.4	10,120	1,355	134
7	♀	40.4	124	15.3	4,130	632	1.8	19.4	45,400	8,810	9	—	—	—	119
8	♀	46.2	123	10.8	2,780	300	2.5	15.3	19,700	3,015	—	—	—	—	131
9	♀	43.4	106	11.2	3,030	340	2.3	6.7	45,000	3,000	—	—	—	—	125
10	♀	41.3	100	10.4	3,300	344	1.5	12.0	38,800	4,660	—	—	—	—	129
11	♀	46.2	136	18.0	2,960	533	2.3	14.2	42,600	6,050	—	—	—	—	138
12	♀	45.6	182	13.5	4,700	635	3.2	11.1	56,600	6,280	17	2.26	42,800	966	130
13	♀	48.6	182	14.0	1,900	266	3.0	49.0	7,600	3,720	8	—	—	—	124
14	♀	46.7	176	10.6	4,160	441	3.0	15.8	43,000	6,800	18	1.76	119,500	2,100	113
15	♀	45.2	167	14.4	1,580	228	2.8	11.9	48,000	5,720	15	2.42	173,000	4,180	135
16	♀	44.6	164	9.0	3,765	339	3.8	10.3	41,200	4,250	11	—	—	—	136
17	♀	43.6	128	15.9	2,365	376	1.0	42.2	21,650	9,150	11	3.58	146,000	5,220	124
18	♀	46.8	169	16.0	1,650	264	2.5	31.2	21,400	6,680	8	—	—	—	143
19	♀	50.7	167	13.3	2,300	306	3.0	18.8	16,400	3,085	—	—	—	—	133
20	♀	44.3	136	12.5	3,300	412	2.8	16.0	30,800	4,930	—	—	—	—	132
21	♀	45.3	127	15.1	2,700	403	2.5	21.4	20,900	4,480	—	—	—	—	127
22	♀	47.4	141	12.7	4,070	516	2.7	18.8	26,500	4,980	—	—	—	—	131
23	♀	51.3	263	16.2	2,620	425	4.5	—	—	3,760	12.8	—	—	1,740	
24	♀	48.2	236	19.5	3,580	698	4.8	—	—	—	39.2	22.43	1,650	371	
25	♀	47.1	205	27.0	1,640	444	4.2	—	—	4,970	8.2	—	—	2,350	
26	♀	46.5	185	—	—	—	3.2	—	—	4,400	10.5	—	—	—	
27	♀	43.5	181	—	—	—	5.3	—	—	5,300	28.0	17.57	4,470	798	
28	♀	51.5	220	17.0	1,460	248	6.5	14.6	15,200	2,220	14.2	19.2	360	69	
29	♀	53.0	200	13.5	3,040	410	6.2	15.4	19,640	3,025	13.4	17.0	130	22	
30	♀	45.5	140	11.8	1,590	188	2.2	20.6	12,200	2,520	—	—	—	—	
31	♀	54.3	250	12.4	1,650	230	5.2	6.9	26,400	1,815	23.7	16.2	2,146	348	
32	♀	53.0	250	18.5	1,270	235	6.3	18.3	9,350	1,715	21.0	22.5	1,670	376	
33	♀	56.5	290	18.4	1,340	246	6.7	9.9	25,400	2,520	18.5	22.9	985	226	
34	♀	50.5	200	13.7	3,620	496	2.7	18.6	29,700	5,500	11.5	1.8	3,150	57	
35	♀	50.5	182	18.4	5,320	980	3.6	29.2	23,600	6,900	11.3	2.1	3,640	75	
36	♀	54.0	286	—	—	315	7.0	—	—	3,070	21.2	—	—	178	
37	♀	52.0	244	—	—	265	6.2	—	—	1,750	19.7	—	—	147	
38	♀	44.8	118	—	—	580	2.0	—	—	3,060	—	—	—	—	
39	♀	42.7	105	—	—	—	1.3	—	—	4,180	5.5	—	—	452	
40	♀	57.6	271	17.9	1,260	226	4.9	27.0	7,050	1,900	15.3	5.3	4,700	250	
41	♀	55.5	243	21.8	780	170	6.6	10.4	9,750	1,010	17.4	9.8	2,365	231	
42	♀	53.2	230	17.9	930	167	5.9	12.0	12,100	1,450	16.0	18.2	920	167	
43	♀	53.0	213	20.5	2,060	423	4.2	33.8	51,200	17,300	11.5	5.7	7,560	428	
44	♀	51.8	225	19.0	700	133	4.4	10.5	11,520	1,210	15.4	18.4	640	117	
45	♀	51.8	205	19.3	1,015	196	4.1	9.5	14,050	1,330	12.9	20.5	1,045	214	
46	♀	51.5	205	21.4	1,200	257	5.2	10.1	12,450	1,250	15.2	20.8	1,064	221	
47	♀	51.0	200	18.6	1,745	323	5.6	5.2	44,800	2,330	15.9	16.4	1,430	234	
48	♀	50.8	232	19.8	1,205	236	4.8	6.3	63,000	3,950	17.3	22.0	990	218

FIG. 2 *Anatomy of the Lamprey*
L, liver; T, testis; O, ovary; I, intestine

(Fig. 2), and their oil and vitamin A contents were determined with the results shown in Table I.

RESULTS

Vitamin A Content of Fresh Fish

1. *Flesh*

Vitamin A content in the flesh per gram of tissue was found to be 99–980 I.U. (average 300 I.U.), the highest value that has ever been observed in the animal flesh. For in chicken, pork, beef and other fishes, the vitamin A content has been found to be as low as 0.5–3.0 I.U. per gram of tissue. Since the authors previously found in other fishes that the vitamin A content in the flesh differs considerably depending upon the locality of the body, an experiment has been undertaken to see if the similar tendency is observed in the lamprey using

FIG. 3 *Locality of the Body of a Lamprey, from where the Sample Flesh was taken*

TABLE II
Vitamin A Content at Various Localities of Flesh
See Fig. 3

Sample Number	Locality of the body	Oil content	Vitamin A in oil	Vitamin A in tissue
		<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>
33	1	14.7	1910	281
	2	23.5	1310	308
	3	19.9	1120	224
	4	15.3	1010	155
34	1	13.8	4700	650
	3	16.4	3160	520
	4	11.0	3000	330
35	1	17.0	9950	1690
	2	22.4	3830	860
	3	13.9	3640	501
	4	20.1	3850	770

antimony trichloride was adopted. Thiamine and riboflavin were determined by thiochrome method and lumiflavin method, respectively; vitamin B₆ and B₁₂ by microbioassay using *Lactobacillus leichmanii*; folic acid by *Streptococcus faecalis* and pantothenic acid by *Lactobacillus arabinosus*. In each fresh sample, the weights of bodies, livers and gonads

FIG. 4 Frequency of the Samples Varying in Amounts of Vitamin A According to Organs and Seasons

the samples taken from the localities shown in Fig. 3. As the results shown in Table II reveal, the oil and vitamin A contents of flesh differ considerably depending upon the locality. The content of vitamin A in the body oil was found richer in the anterior part than in the posterior.

According to a previous work by the authors (4), the relation between the oil content ($F\%$) in the flesh of any fish and the vitamin A content (I.U.) of the oil can be expressed by the equation $A F^a = \text{const}$, where a is a constant. When the results shown in Tables I and II were tested, however, the oil content of the flesh and the vitamin A content in the oil were found quite indifferent. Comparing the samples (Nos. 28–48, Table I) caught prior to the spawning stage with those (Nos. 1–25) caught during the spawning season, one may notice that the vitamin A contained in the former group is by far richer than in the latter (Fig. 4). The iodine number of the body oil, 111–138, showed no relation at all with the body weight, oil content or vitamin A content of the flesh.

2. Liver

In the liver, generally weighing 2.3 per cent of the body, vitamin A was found 1,010–17,300 I.U./g, nearly 10 times as much as that of the flesh. Though

FIG. 5 Relation between Vitamin A Content and Fat Content in Liver

the livers of tunas and dogfish sometimes show still higher level than above, there is no doubt that vitamin A level in the lamprey liver is definitely higher than that of ordinary fishes. In regard to the vitamin A content, the similar seasonal tendency has been observed in the livers as was the case in the flesh. A relation between the oil content of the liver and the vitamin A in that oil is shown in Fig. 5; the lower the oil content of the liver, the richer was vitamin A in the oil.

3. Gonads

In the spawning season, the testis of lamprey contains 966–5,220 I.U. of vitamin A per gram of tissue. Since in the testis of ordinary fishes or animals the vitamin A is hardly detectable, it is most remarkable to find that only the lamprey contains such a large quantity of the vitamin in the testis. Vitamin A in the gonads of lamprey is far richer in the samples of spawning season than those of autumn, though it varies considerably depending upon individuals, especially in samples obtained in spawning season.

4. Kidney

On some samples, the vitamin A content of kidney was tested (Table III). According to the authors' experiments (5), sharks have the kidney rich in vitamin A. Nevertheless, the lamprey kidney contains the vitamin ten times as

TABLE III
Vitamin A Content in Kidney

Sample number	Weight	Oil content	Vitamin A in oil	Vitamin A in tissue
	<i>g</i>	<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>
40	2.1	8.1	17,000	1,450
41	2.0	5.1	50,800	2,630
42	1.8	4.0	50,750	2,010
43	1.8	11.8	65,600	7,760
44	1.6	4.7	33,100	1,550
45	1.4	5.5	28,100	1,540
46	1.6	6.5	40,000	2,600
47	1.3	6.4	79,100	5,060
48	1.7	6.2	39,000	2,400

much as that of sharks.

5. Digestive Organs

Vitamin A in the digestive organs of lamprey was determined. To distinguish the stomach from the intestine by their appearances was difficult because the organs look just like a single tube. A pale yellow, milky substance observed in the tube did not seem to be the residue of the diet, because all the sample fishes were kept alive more than a week without any food. Instead, the milky substance may possibly have been excreted in the intestine from the tissue. As shown in Table IV, the vitamin A content in the tract was found extraordinary higher than that of the flesh, liver or gonads.

TABLE IV
Contents of Vitamin A and Oil in Digestive Organs
Sample Nos. 40—48 were caught in December 1956.
Sample Nos. 49—53 were caught in February 1955.

Sample number	Digestive organs				Contents in digestive organs			
	Weight	Oil content	Vitamin A in oil	Vitamin A in tissue	Weight	Oil content	Vitamin A in oil	Vitamin A in contents
	<i>g</i>	<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>	<i>g</i>	<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>
40	1.35	9.06	422,000	38,100	1.20	5.34	122,000	6,520
41	2.07	6.98	438,000	30,600	1.85	4.20	94,800	3,980
42	1.63	6.81	394,000	26,800	1.12	6.40	183,200	11,720
43	1.22	15.67	725,000	113,600	0.20	9.80	93,200	9,120
44	0.78	6.24	292,000	18,200	0.77	8.15	197,600	16,100
45	1.09	6.39	293,000	18,700	0.82	7.67	120,300	9,240
46	0.87	9.87	508,000	50,200	0.73	6.30	225,500	14,200
47	1.13	11.62	572,000	66,500	0.62	8.18	222,500	18,200
48	1.32	8.74	517,000	45,200	1.13	5.56	112,600	6,260
49	0.51	—	—	73,700	0.90	—	—	4,450
51	0.42	—	—	113,200	0.60	—	—	36,700
52	0.38	—	—	108,000	0.40	—	—	69,900
53	0.37	—	—	95,500	0.55	—	—	32,200

6. Distribution in the Body

The distribution of vitamin A in the body of lamprey has been calculated

(Table V). Vitamin A in the flesh and digestive organ accounts for 29—48, and 25—53 per cent of the total vitamin A, respectively; both put together amounting to 80 per cent of the total, whereas the remaining 20 per cent of the total being shared among the liver, kidney and gonads.

These data emphatically suggest that the lamprey is quite an exceptional species of fish. For, in most fishes, the liver, sometimes together with pyrolic caeca, accounts for nearly 90 per cent of the total vitamin A in the body.

TABLE V
Distribution of Vitamin A in Body

Sample number	Sex	Flesh	Liver	Sexual organ	Kidney	Digestive organ excluding contents
		<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
40	♂	43.8	7.4	3.3	2.5	43.0
43	♂	25.5	23.7	1.6	4.6	45.3
41	♂	37.2	7.5	4.3	5.3	45.6
42	♂	34.8	9.8	3.3	4.3	47.8
44	♂	53.0	10.2	4.1	4.1	28.6
45	♂	53.2	7.8	4.7	3.1	31.2
46	♂	43.1	6.9	2.9	3.9	43.1
47	♂	35.8	8.5	2.6	4.6	43.8
48	♀	34.8	14.8	3.0	3.0	44.4

7. Lamprey Larvae

The larvae of lamprey are brownish in color and semitransparent at the earliest stage, then gradually change into the young form. Some samples in a very young stage collected from upper streams of the Mogami showed a comparatively high level of vitamin A even at that stage (Table VI), though the older ones contained vitamin A in the flesh and liver more than the younger.

TABLE VI
Vitamin A Content in Young Fish

Sample number	Body length	Body weight	Flesh			Liver		Internal organs		Notes
			Oil content	Vitamin A in oil	Vitamin A in tissue	Weight	Vitamin A in tissue	Weight	Vitamin A in tissue	
	<i>cm</i>	<i>g</i>	<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>	<i>g</i>	<i>I.U./g</i>	<i>g</i>	<i>I.U./g</i>	
1	16.5	6.6	10.25	122	12.5	0.061	440	0.423	37.5	Some green vegetable-like substance was observed in the intestine.
2	16.0	6.9	8.48	156	13.2	0.059	406	0.399	62.6	
3	14.3	4.7	7.63	142	10.1	0.079	216	0.168	160.0	
4	13.7	4.1	5.20	172	8.6	0.042	286	0.285	31.7	
5	13.0	3.0	5.45	154	8.4	0.042	362	0.139	105.0	
6	10.6	2.2	3.69	256	9.5	0.025	251	0.123	75.3	Before metamorphosis, the body showed a semi-transparent brown colour.

Vitamin A Content in Dried Lamprey

The lamprey is often sold in a dried form at special drug stores. The drying process is simple and needs neither salt nor anything more than keeping the fish in an airy shade. Tests of some samples from market yielded very rich contents of vitamin A as given in Table VII, proving the dried form as

TABLE VII
Vitamin A Content of Dried Lamprey

Sample number	Body length	Body weight	Oil content in flesh	Vitamin A in oil	Vitamin A content in flesh
	<i>cm</i>	<i>g</i>	<i>per cent</i>	<i>I.U./g</i>	<i>I.U./g</i>
53	51.5	90.0	37.5	974	365
54	42.5	55.0	39.5	4,060	1,620
55	50.5	97.0	42.0	3,700	1,550
56	48.5	87.0	46.8	3,760	1,760
57	49.5	97.0	46.4	1,200	550
58	43.7	54.0	44.0	2,680	980

an excellent source of vitamin A. In an experiment to see the loss of vitamin A during the drying process, the fresh sample with the viscera removed, was washed in water, dried in an outdoor shade, after testing vitamin A on a part of the body. Upon drying, vitamin A was tested with a piece of the samples taken from the same locality as tested previously. In two samples dried for 18 days, vitamin A of the oil was found to have decreased during the drying process, whereas in three samples dried for 40 days, the vitamin increased remarkably (Table VIII). In the absence of a conclusive reason, a possible

TABLE VIII
Change in Vitamin A Content during the Production of Dry Lamprey

Sample number	Fresh state		Number of days for drying	Dried state	
	Oil content	Vitamin A in oil		Oil content	Vitamin A in oil
	<i>per cent</i>	<i>I.U./g</i>	<i>days</i>	<i>per cent</i>	<i>I.U./g</i>
60	19.6	1,150	18	41.5	770
61	15.5	3,770	18	50.9	2,020
62	16.2	2,620	40	42.0	4,150
63	19.5	3,580	40	31.9	6,300
64	27.0	1,640	40	41.5	2,710

explanation of the phenomena is as follows. While the locality from where the sample had been taken at the beginning might have been poorer in vitamin A, it was supplied during the course of preparation with some vitamin-rich oil transferred from elsewhere and eventually tested. Though the attempt failed to assess the loss of vitamin A in the drying process, it is certain that the lamprey contains much vitamin A even in the dried materials.

Contents of Water-Soluble Vitamins

Tables IX and X present the contents of thiamine, riboflavin, vitamin B₆, B₁₂,

folic acid and pantothenic acid of the flesh, liver, gonads, skin and mucoid

TABLE IX
Contents of Vitamins in Lamprey

B₁, thiamine; B₂, riboflavin; B₆, vitamin B₆; B₁₂, vitamin B₁₂;
v, ventral side; d, dorsal side.

Sample number	Sex	A	B ₁	B ₂	B ₆	B ₁₂
		I.U./g	μg/g	μg/g	μg/g	mμg/g
Gonads						
23	♂	1,740	0.78	2.78	0.5	46
24	♀	371	1.21	4.88	3.6	56
25	♂	2,350	2.51	3.12	1.1	83
26	♂	—	—	3.75	—	—
27	♀	798	—	6.30	—	—
49	♀	205	0.67	4.00	3.4	115
50	♂	428	—	1.98	1.2	28
Skin						
23	♂	{ v 32.2 d 27.9	{ — 2.81	{ 2.22 22.2	{ (1.1) 1.4	{ 20 21
24	♀	{ v 38.7 d 37.2	{ 9.04 1.74	{ 26.6 21.7	{ 1.1 (0.4)	{ 12 15
25	♂	{ v 32.4 d 23.8	{ 6.35 2.86	{ 22.6 24.3	{ 0.6 (1.3)	{ 8 12
26	♂	—	—	—	—	—
27	♀	—	—	—	—	—
49	♀	{ v — d —	{ 10.78 1.26	{ 22.08 10.62	{ 1.4 2.6	{ 38 26
50	♂	—	—	—	—	—
Mucin-like substance of skin						
23	♂	2.24	—	—	—	—
24	♀	1.31	—	—	—	—
25	♂	10.00	—	3.0	—	—
26	♂	—	—	1.38	—	—
27	♀	41.60	—	1.36	—	—
49	♀	—	—	—	—	—
50	♂	—	—	—	—	—
Flesh						
23	♂	462	0.94	1.6	1.6	54
24	♀	551	—	—	—	—
25	♂	444	1.48	6.93	1.8	33
26	♂	—	—	—	—	—
27	♀	—	—	—	—	—
49	♀	277	0.46	6.12	2.2	38
50	♂	423	—	—	—	—
Liver						
23	♂	3760	0.74	9.01	1.1	12
24	♀	4030	4.16	6.67	2.0	34
25	♂	4970	1.34	6.01	2.7	35
26	♂	4400	—	9.33	—	—
27	♀	5300	—	7.48	—	—
49	♀	5600	0.05	8.40	1.4	230
50	♂	17300	—	—	—	—

substance of the skin; Table IX including the vitamin A contents for the convenience of comparison. Vitamin B₁₂ in the flesh and skin as well as thiamine in the skin was assessed by far richer than in ordinary fishes. Furthermore, regarding the riboflavin content in the skin, the lamprey seems to belong to the richer group including flatfishes and eel.

As for individual variability, the riboflavin content in the liver, gonads, and skin, varied considerably but less than other water-soluble vitamins named above. In case of variability by positions of the skin, attention should be drawn to the following. Despite considerable variances in the riboflavin content between the dorsal and ventral sides of ordinary fish skin as reported by Washino (6), no such a tendency was obvious in riboflavin content of the lamprey skin. On the other hand, thiamine of the lamprey was found much more in the ventral skin than in the dorsal one, exhibiting a striking contrast with the previous assessment in which the authors found no difference in thiamine content in ordinary fish skin regardless of the positions of the skin. These findings lead to the characteristics that make the lamprey exceptional from any other fish. In Table X showing the content of folic acid and pantothenic acid in the various organs of lamprey, the amount of folic acid in the liver was noticeable, though both acids in the other organs tested differed little or not at all from those in other fishes.

TABLE X
Contents of Folic Acid and Pantothenic Acid in Various Organs of Lamprey

FA, folic acid; PA, pantothenic acid.

Sample number	Sex	Flesh		Liver		Kidney		Heart		Sexual organ		Skin	
		FA	PA	FA	PA	FA	PA	FA	PA	FA	PA	FA	PA
51	♀	0.24	2.8	5.37	12.0	0.53	trace	0.45	5.0	0.55	15.6	0.28	trace
52	♂	0.29	5.7	4.07	14.0	—	—	—	—	0.97	8.7	—	—

The sample were caught in November 1957.

DISCUSSION

As mentioned above, the lamprey is quite extraordinary in regard to vitamins, especially vitamin A. An interesting problem — on what sort of food the fish live during their sea life — remains to be solved. At any event, however, the lamprey appears to eat and accumulate a large quantity of vitamins possibly much more than it consumes for its existence. The above supposition has been confirmed in the feeding experiments of rats with a very large quantity of vitamin A. For, the result indicated an abnormal accumulation of the vitamin in the liver as well as in the kidney and flesh, in the latter of which the vitamin A content was nearly as high as that of the lamprey. But it is difficult to analogize from the data of rats why the lamprey possesses so rich vitamin A in the testis, because the results from the rat testis were hardly

comparable with those from the lamprey's. The vitamin content in the samples in spawning season was richer than in the autumn. Nevertheless, the increase in the amount does not seem to be ascribable to natural food for the lamprey, because plants, insects or small fishes sampled in the rivers in different seasons were not so high in vitamin A or carotene as the lamprey. Judging from the information given by the local fishermen — the lamprey becomes smaller in size towards the spawning season — it is possible that the size of the same fish decreases during the course of maturity if the fish consumed its muscles for the formation of gonads or the energy source, thus resulting in the concentration of vitamin A in the tissue. But this seems to require further confirmation. It may be worth adding here that vitamin A of *Lampetra planeri* and *Heptatretus okinoseanus*, both taxonomically close allies to the lamprey under report, was tested. The content obtained, however, was much inferior to that of the lamprey (Table XI).

TABLE XI
Vitamin A Content in the Species Allied to Lamprey

Species	Body length	Body weight	Flesh			Liver	
			Oil content	Vitamin A in oil	Vitamin A in tissue	Weight	Vitamin A in tissue
<i>Lampetra planeri</i> Bloch	cm 10.5—6.0	g 2.1—0.5	per cent 5.88	I.U./g 118	I.U./g 6.9	g —	I.U./g —
<i>Heptatretus okinoseanus</i> Dean	42.0	165	1.79	66.4	1.2	3.2	28.1

Distributions of the water-soluble vitamins in the lamprey are no less peculiar than the other vitamins in giving this species an outstanding position among fish. A view that the function of these vitamins in the body of lamprey may be fairly different from that of ordinary fish has been suggested from the major findings of the present work: the high content of thiamine in the skin, its considerable variances between the ventral and dorsal sides in contrast with riboflavin which showed no difference, and remarkable richness of B₁₂ in the flesh and skin.

In conclusion, a normal amount of a man's diet, if it consisted of the lamprey flesh, would likely afford to supply more than ten thousands I.U. of vitamin A, together with thiamine, riboflavin and vitamin B₁₂ in much larger amounts than in an ordinary meal. These may possibly be the reasons why the lamprey has been so highly evaluated in this country as an excellent source of nourishment since a number of years ago.

SUMMARY

Vitamin contents were tested with the lamprey caught in the Mogami River, Yamagata Prefecture. In the flesh, the vitamin A level was found the highest ever known in the flesh of any species of fish or animal. Anatomical parts

rich in vitamin A next to the flesh are the liver, kidney, gonads and intestine; especially, the testis and intestine contain extraordinary quantities of the vitamin. The distribution of vitamin A in the body considerably differs from that of ordinary fishes. The major part of the vitamin is accumulated in the flesh and intestine, whereas the liver possesses only a small part of it.

Samples caught in the spawning season, April and May, were found more abundant in the vitamin content than those caught in autumn. The young fish also indicated by far higher content of vitamin A than any other fish in a comparable stage.

The content of thiamine and B₁₂ in the skin greatly exceeds that of other fishes. In the ventral skin more thiamine was found than in the dorsal skin.

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