The Chemistry of Growth and the Food Value of the Common Eel (*Anguilla anguilla* (L.))

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As an article of diet the eel must have a literature dating back for centuries, and although its scientific history cannot claim to go back quite so far, it is nevertheless full of interest. Its life cycle has been shown to include two of the most remarkable migrations known to man. Many excellent investigations, beginning with the famous ones of Paul Bert, have been devoted to the way in which it regulates its osmotic pressure during its passage from inland waters to the sea. A few scattered but, on the whole, incomplete data are available on its composition at maturity and during growth. No study of the kind now to be described appears, however, to have been made.

METHODS

The eels were obtained through the Freshwater Biological Association of the British Empire and were all caught in the north of England. The elvers, which were obtained in 1943 and 1944, had been kept in fresh water for a few weeks before they were sent to Cambridge. The 'snigs', i.e. the small yellow eels weighing about 10 g. apiece, were taken in the years 1943 and 1944 in the river Wyre, Lancs. The yellow eels were caught in 1943 on lines in the Windermere catchment area, and the silver eels in the same year on migration from this area to the sea. The eels were sent to Cambridge packed in grass or weed and the majority were alive on arrival. Yellow eels and the snig eels were obtained in the early summer and again in the autumn, but the elvers and silver eels only when they were migrating. On arrival at Cambridge the eels were measured and weighed. Elvers and one batch of snigs were analyzed whole, but the second and third batches of snigs, and all the larger eels were skinned and dissected with stainless steel knives and scissors. The soft parts were then cut up into small enough pieces to allow duplicate samples, generally of 50 g., to be weighed out for mineral analysis. The remainder was usually minced to facilitate the sampling for nitrogen and fat. At first only muscular tissue was analyzed, although the skins, and the head and guts, were weighed; later the skins, heads and organs were also analyzed so that the composition of the whole fish might be computed. It was, however, impossible to sample the heads and bony parts without mincing them, and hence without running a very serious risk of contaminating them with iron. In all, 51 snigs, 30 yellow eels of assorted sizes and 30 silver eels have been analyzed. The silver eels varied very much in size but were all females. Batches of 4-14 animals have been handled together according to their size and to the numbers received, and their tissues pooled for analysis.

The chemical methods have in the main been those described by McCance & Shipp (1933) or by McCance, Widdowson & Shackleton (1936). Sodium was precipitated

as described by these authors and the precipitate titrated with 0.02N-NaOH (Weinbach, 1935). Water was determined by drying to constant weight at 95-100°. Protein has been taken as $N \times 6.25$. The vitamins were determined by Drs T. Moore, E. Kodicek and Y. L. Wang at the Dunn Nutritional Laboratory, Cambridge. Vitamin A was assayed by the antimony trichloride method, aneurin by the procedure of Harris & Wang (1941, 1942), nicotinic acid by the *p*-aminoacetophenone method (Kodicek, unpublished), and riboflavin by a fluorimetric method (Kodicek & Wang, unpublished).

RESULTS

The chemical composition of whole eels

Table 1 gives the percentage composition of animals at four stages of their development. The elvers were of the order of 0.25 g. in weight, and the amounts of water, N and fat found in them were of the same magnitude as those given by previous analysts. Nitrogen, for example, has been reported to vary from 1.88 to 2.27% and fat from 2.3 to 4.17% (Vaillant, 1903; Reuss & Weinland, 1913; Boucher-Firly, 1935). The snigs averaged 9.4 g. The yellow eels analyzed for Table 1 averaged 197 g., but there is reason to believe (see later and Table 4) that eels of about 100 g. in weight would have had very much the same composition. The figures given for the silver eels are the means of one batch which averaged 197 g. and another which worked out at 1400 g. Size made little difference to their percentage composition. It is at once evident that development involved fundamental changes. There was a progressive and continuous fall in the percentage of water. Between the elver stage and the snig stage this was associated with a considerable increase in protein and a trifling one in fat. Reuss & Weinland (1913) detected these changes in elvers which had been kept and fed in captivity for only 50 days. Such alterations of chemical structure are characteristic of the early growth of many animals and are very well shown by mammals up to and for a variable time after birth (Reuss & Weinland, 1913; Shohl, 1939). As the eels grew and developed further, fat accumulated in them, and this fat displaced both water and protein. Hence the percentage of water continued to fall but with it now the percentage of protein. At maturity, i.e. in the silver eels, these changes were seen in their most exaggerated form for the animals were then loaded

with fat, the protein had fallen to 15.6% and the water to 59.7%. Nevertheless, expressed on a fat-free basis there had been little change since the snig stage in the amount of protein in their bodies, or in the water protein ratios, and this is typical of the later stages of mammalian growth (Moulton, 1923; Shohl, 1939). The eel is a fat fish but by no means a very fat animal. The full-term baby contains about 12% of fat, most of which has been accumulated in the last 8 weeks of foetal life; a normal man is reckoned to be about 18% fat, a woman would be more, say 25%—figures quite comparable with the eel. Pigs fatten up easily from about 1.2% at birth (personal observations) to 11% of fat at 75 days old and 42% at 264 days (Ellis & Hankins, 1925).

older eels, and it is interesting to note that the figures found for the latter agreed quite well with the one for human serum. This, of course, was to be expected from what is known of the osmotic pressures of mature eels and other vertebrates.

The figures for the alkaline earth metals deserve some consideration. After the eel has been in fresh water for about 3 years, calcium begins to be deposited not only in the bones (as in mammals) but also in the scales which are buried in the skin. Hence, whereas 99% of the body calcium of man is in the bones (Shohl, 1939), and this is probably true also of the elvers and young snigs, only 86% of the calcium in the bodies of yellow eels was found in the bones and 75% of that in the silver eels. Never-

Table 1. *The composition of eels at various stages of their growth and development*

Eel type	Water (g./ 100 g.)	Protein (g./ 100 g.)	Fat (g./ 100 g.)	Na (mg./ 100 g.)	K (mg./ 100 g.)	Ca (mg./ 100 g.)	Mg (mg./ 100 g.)	Fe (mg./ 100 g.)	P (mg./ 100 g.)	Cl (mg./ 100 g.)	N (g./ 100 g.)
Elvers	81.8	12.6	2.19	67	230	515	31.0	4.00	440	55.4	2.02
Snigs	76.5	19.0	2.50	110	302	610	28.0	1.80	475	52.0	3.04
Yellow eels	70.8	17.2	10.60	129	247	411	23.1	1.33	419	92.6	2.75
Silver eels	59.7	15.6	23.20	92	207	323	18.0	1.83	313	79.0	2.51

For osmotic reasons the concentrations of Na and K must be considered together with those of water, for changes in the one without the other would involve violations of the animals' osmotic pressures. It will be seen that there was a rise in the concentrations of Na and K in passing from the elver to the snig stage. This was associated, as already mentioned, with a fall in the percentage of water, and must have meant a rise in osmotic pressure, and it is in keeping with the facts (a) that the elvers were analyzed after they had been in fresh water for a little time, (b) that in elvers the power to regulate osmotic pressure is not yet fully developed (Boucher-Firly, 1935). The fall in water as the eels grew from the snig stage and matured was accompanied by a fall in the sum of the milliequivalents of Na + K in the animals. If twice the sum of the concentrations (in m.equiv./l. of body

theless, the amount in the skin is a relatively small and constant fraction of the total calcium of the body (see later, and Table 4), so that gross accretions in body calcium may be considered, as in the mammal, to represent bony growth. The rise, therefore, in the percentage of calcium in the body between the elver and the snig stage may certainly be assumed to be associated with the formation of the bones and the deposition of calcium therein at a greater rate than the general increase in body weight. A changing relationship of this type was detected by Reuss & Weinland (1913) in elvers, and characterizes the early growth of all vertebrates. As the snigs developed into larger yellow eels and finally matured to silver eels the percentage of calcium fell. To a limited extent this was due to the deposition of fat, but it is at these later stages that the rate at which calcium is deposited in the eel (and probably in all fish without a high degree of scale development) diverges from the rate at which it is deposited in a land animal. To show this Table 3 has been compiled from Shohl (1939) and from Duckworth & Warnock (1942). It shows, in g. or mg./100 g., the fat, calcium and magnesium, in a human being at various ages. The diverging trends for calcium in man and eel are due to the different degrees of bony development required by aquatic and land animals. It would be interesting to have similar data for aquatic mammals.

Comparative bony development also explains why the eel has a much smaller percentage of 'total ash' in its body than a land animal. Thus the pig and man have about 3% of ash in their fat-free bodies

Table 2. *Osmolar concentrations in eels*

Eel types	mM. of osmotically active material/l. of tissue water
Elvers	215
Snigs	328
Yellow eels	337
Silver eels	307
Human serum (on the same basis)	318

water) of Na and K be taken as a measure of osmotic activity, the data for osmotic activity given in Table 2 can be calculated from the figures shown in Table 1. It will be seen that the osmotic pressure in the elvers was well below that in the

Table 3. *The concentration of fat, calcium and magnesium in human bodies*

Age	Fat (%)	Ca (mg./100 g. of whole body)	Mg (mg./100 g. of whole body)
Foetus: 4 months	0.5	340	18.0
6 months	2.5	605	20.5
Premature baby, 7 months	3.0	726	21.4
Full-term baby	12.0	810	23.7
Child, 10 years	15.0	2000	—
Adult	18.0	2300	29.5

(This table is based on the data of Shohl (1939) and Duckworth & Warnock (1942).)

at birth, and this percentage rises with development (Moulton, 1923; Ellis & Hankins, 1925). If the percentage of total ash (and therefore of calcium) in a land animal appears to fall in the later stages of growth, as it has been shown to do in the pig (Ellis & Hankins, 1925), it can be accounted for entirely by deposition of fat. By calculating the elements in Table 1 as oxides or chlorides, the snigs can be shown to have had only 2.6 % of ash in their bodies, and this percentage fell with growth so that the silver eels contained only 2.1 % of ash on a fat-free basis.

In the eel (Table 1) the percentage of Mg in the body was found to fall from the elver stage to

Ca and Mg to vary together. In man they do so, and in the eel they do so too after the snig stage. The large amounts of Mg in the elvers, however, can hardly be attributed to their bony development, for they contained less Ca than the snigs, but it may be associated with the fact that these animals have only recently left sea water, which is rich in Mg salts.

The amount of P in the body depends upon the degree of bony development and the figures, therefore, follow those for calcium, but the changes are smaller because in the eel there is relatively more P outside the bones and skin, and, therefore, the bony changes are to some extent 'buffered' by the stable composition of the tissues.

The figures for Na, K, Ca and Mg can be regarded in another way. These four cations together constitute so nearly the whole of the total base of the body that they may be assumed to do so. If their sum be taken as 100, the results shown graphically in Fig. 1 are obtained, and the corresponding data for a human being taken from Shohl (1939) and Duckworth & Warnock (1942) are given beside them. In the earlier stages of development both young animals would have shown a progressive increment in the percentage of calcium. The divergence later is well shown in the diagram.

Fig. 1. A comparison of the percentage 'make-up' of the total base in the human body and in the eel at various stages of development.

maturity: in man (Table 3) it will be seen to rise throughout the period of growth. According to Duckworth & Warnock (1942), 80 % of the Mg in a man is in the bones, and the corresponding percentage in the eel, though smaller, must be considerable. Consequently, in both animals, one would expect the extent to which the skeleton was developed and mineralized to determine the percentage of Mg in the body, and the percentages of

The striking thing about the figures for iron are the large amounts of this element found in the elver. If this accumulation of iron could be shown to have any biological significance it would be very interesting. Mammals are born with an accumulation of iron in their bodies, and this has been regarded rather teleologically as a provision of nature for the low iron intakes of the suckling period. It may be, however, that storage of iron is

characteristic of some phase in the development of all vertebrates.

The composition of tissues and organs

Table 4 shows the composition of the muscular tissues of eels at various stages of development, of the livers and skins taken from yellow and from silver eels, and of the heads, guts, livers and bones taken together.

results are also in conflict with those of Lovern (1938), and it is worth noting that by 1940 Lovern was himself beginning to find exceptions to his 'fat-length' generalization. Muscle tissues, like the whole animals, show a fall in both water and protein with each increment of fat, and also a relatively constant water-protein ratio whatever the level of fat (Moulton, 1923). Mammalian work suggests that some muscles would be consistently fatter than

Table 4. *The percentage composition of eel organs*

Eel type and average weight	Water (g.)	Protein (g.)	Fat (g.)	Na (mg.)	K (mg.)	Ca (mg.)	Mg (mg.)	Fe (mg.)	P (mg.)	Cl (mg.)
Muscle:										
Snigs 9.4 g.	78.0	18.0	3.1	76	290	26.0	18.7	0.50	210	74
Yellow eels 103.0 g.	71.0	17.0	11.2	62	281	21.5	20.4	0.90	226	50
Yellow eels 193.0 g.	71.5	16.2	11.4	115	251	15.5	17.5	0.53	220	63
Silver eels 197.0 g.	58.3	14.0	26.7	77	190	16.3	14.3	1.17	190	55
Silver eels 333.0 g.	53.8	15.3	29.8	85	236	11.6	14.4	0.76	192	111
Silver eels 678.0 g.	59.1	14.6	26.4	97	191	13.3	14.9	0.54	190	62
Silver eels 1400.0 g.	57.0	13.5	28.3	50	243	9.3	13.9	0.53	197	49
Liver:										
Yellow eels 188.0 g.	78.7	14.3	4.7	165	221	6.5	13.5	25.00	277	—
Silver eels 333.0 g.	77.9	13.2	6.5	203	196	8.9	11.4	105.00	244	193
Skin:										
Yellow eels 188.0 g.	—	22.8	5.2	105	126	468.0	17.2	0.86	350	—
Yellow eels 197.0 g.	68.0	25.2	5.2	147	183	585.0	19.1	2.67*	445	184
Silver eels 197.0 g.	66.5	25.8	6.2	144	148	670.0	19.4	5.25*	405	156
Silver eels 333.0 g.	—	27.5	5.2	194	121	730.0	16.2	1.05	439	—
Heads, guts, livers, bones together:										
Yellow eels 197.0 g.	69.7	17.1	9.3	168	224	1240.0	35.4	3.1*	805	129
Silver eels 197.0 g.	59.8	16.0	16.9	135	204	1230.0	35.4	3.4*	715	93
Silver eels 1400.0 g.	60.1	15.7	19.1	150	174	1060.0	26.5	6.7*	515	123

* Minced.

Muscular tissue constitutes about two-thirds of the total weight, and forms the main fat depot of the animal. It will be seen from the table that yellow eels of rather varying sizes tended to have about 11% of fat in their muscles, whereas the silver eels had 26–30%. Each figure given in Table 4 is the average of at least four animals, and there is no doubt that the individuals varied very much on either side of these means. Boucher-Firly (1935) found that the muscles of small eels weighing 20–25 g. contained 4.5–21.4% of fat and averaged 13.5%. These figures seem very high for eels of that size, but the larger animals must accumulate fat in their muscles preparatory to their metamorphosis and migration, and so very fat ones must occasionally be caught, but the number of yellow eels with more than 15% of fat in their muscles is probably only a very small proportion of the total eel population of our rivers and lakes. Be that as it may, these results do not support Lovern's (1938) contention that the amount of fat in an eel can be foretold from its length. Lovern did not state whether his eels were all immature yellow animals, but from the nature of his experiments it may be assumed that they were. Boucher-Firly's (1935)

others, and that some might accumulate fat at an earlier age than others, but no information about this is available.

The eel was one of the animals which Katz (1896) included in his classical survey of the minerals to be found in muscular tissue. He analyzed two large eels and his figures for Na, K, P and Cl are near those given here for the largest silver eels. In the present study the sodium in the muscles varied from 48 to 115 and the potassium from 190 to 281 mg./100 g. No doubt the individuals varied much more. The ratio of potassium to nitrogen also exhibited rather wide variations. The chemical evidence, therefore, suggests that the concentrations of minerals in the cellular and extracellular compartments of the muscle mass of the eel may not be so constant as they are in the mammal. Alternately the cellular-extracellular ratio of the muscle mass may vary considerably. Table 4 shows that there was no consistent change in the Na/K ratio as the animals put on fat, so that the fat may be regarded simply as 'diluting' the whole of the watery phase of the muscles.

The figures given for muscular calcium in Table 4 are probably in all cases a little too high, due to the

inclusion of minute bones. They are, however, lower than those of Katz (1896). The figures for Mg bear some relationship to the protein, which is to be expected since the magnesium is almost confined to the cells. The P varies in a similar way. The Fe is on the low side, even for fish muscle.

The livers of the yellow eels averaged 1.5% of the weights of the whole animals, and those of the silver eels 2%. They contained rather more water and less protein than the muscles of the corresponding animals and considerably less fat. Boucher-Firly (1935) found a rather higher percentage of fat in the livers of both yellow and silver animals, but again considerably less than in the muscles. The livers resemble those of mammals in containing little calcium and less magnesium than the muscle (McCance & Widdowson, 1940). This difference is probably associated with function and may be common to all vertebrates. The Fe was exceedingly high, particularly in the silver animals, and Fe storage must be one of the functions of the organ as it is in the higher vertebrates. It may be that the accumulation of Fe in the liver is as much a part of the preparation for migration as the storage of fat in the muscle. The livers contained more sodium and chlorine than the muscles.

The skin, excluding that of the head, constituted about 8% of the weight of the yellow eels, and 10–12% of that of the silver eels. It contained little fat, whatever the fat reserves of the animals, but a very high percentage of protein, twice as much in fact as the liver in the case of the silver eels. The sodium and chlorine were relatively high and the potassium low. The high figures for calcium and phosphorus are due to the calcified scales embedded in the skin, and these scales certainly contained some of the Mg. The true figure for Fe is probably of the order of 1 mg./100 g.

The heads, guts, livers and bones together constituted 25–28% of the yellow eels and 20–22% of the silver eels. These figures include a certain amount

of muscular tissue which was left on the vertebrae and small bones. The vertebrae themselves, when carefully cleaned, came to between 4 and 5% of the animals' weight, and with the bones of the head would come to a little more. The figures for minerals require little comment, except to note the very high values for Ca and P. The bones in all probability contained enough Mg to account for the high figures of 26–35 mg./100 g. in the mixed organs. The figures for Fe may be too high owing to the tissues having been contaminated while they were being minced, but some blood was always lost while the animals were being dissected and gutted, and the two errors would have tended to cancel themselves out.

The sum of the sodium and potassium salts in each litre of tissue water has been determined in each of these organs. In general the data thus obtained were similar to those for the whole animals (see Table 2), but in any one batch the mixture of bones, heads, guts and livers has always given a figure higher than that of the muscles or skin. The explanation for this may be that fish bones, as mammalian bones, contain a certain amount of sodium adsorbed on to the crystals of hydroxy-apatite (Hodge, Koss, Ginn, Falkenheim, Gavett, Fowler, Thomas, Bonner & Dessauer, 1943). Such sodium would be osmotically inactive.

Growth increments

Table 5 shows the length, weight, approximate age and the total amounts of protein, fat and minerals in eels at various stages in their development. This gives at a glance their rate of chemical growth. The total caloric value of these animals may be calculated from their organic composition, and if their metabolic rates could have been determined at representative times of year one could have calculated at once the calorific value of the food they had eaten at each stage of their lives. In a similar way, if the amount and composition of the

Table 5. *The weights of protein, fat and mineral elements in eels at various stages of their growth and development*

Eel type	Length (cm.)	Weight (g.)	Approx. age* (years)	Water (g./ eel)	Protein (g./ eel)	Fat (g./ eel)	Na (mg./ eel)	K (mg./ eel)	Ca (mg./ eel)	Mg (mg./ eel)	Fe (mg./ eel)	P (mg./ eel)	Cl (mg./ eel)
Elvers	7.3	0.25	2–3	0.205	0.032	0.006	0.17	0.58	1.29	0.08	0.01	0.11	0.14
Snigs	22.6	9.4	6–7	7.100	1.890	0.290	10.30	27.2	55.2	2.90	0.153	44.60	6.95
Yellow eels:													
(1)	38.0	103	9–10	73.6	17.100	10.300	136	231	372	27.50	1.22	371	84.4
(2)	49.5	197	12–13	140	33.900	20.900	254	486	810	45.60	2.62	825	183
Silver eels:													
(1)	49.3	197	10–12	118	31.100	43.500	201	373	720	38.40	4.23	617	149
(2)	57.0	333	13–14	195	52.400	84.000	356	716	1030	59.30	5.42	1090	398
(3)	70.2	678	16–18	409	107.000	152.000	775	1260	2100	124.00	12.30	2250	587
(4)	86.6	1400	18–21	810	216.000	340.000	1160	3010	3920	232.00	36.30	4100	1140

* From time of hatching.

food eaten were known, one could calculate the percentage of the minerals in it which had been retained. The figures require no particular comment but there is one point of interest which must be discussed. It will be noted that the larger yellow eels and the smallest silver eels averaged exactly the same weight. This hypothetical yellow eel contained a little more protein, but much less fat than the silver eel, more water, Na and K, however, and also more Ca, Mg and P. This comparison demonstrates the complexities of the change from yellow to silver. Unless the process is accompanied by a loss of Ca and P, the figures for these elements suggest that a yellow eel weighing, say 200 g., cannot turn into a silver eel weighing less than 250 g.

As all sea fish, they would no doubt be rich in iodine. Eels are usually eaten stewed, and this process leads to a loss of nutrients (McCance & Shipp, 1933) unless the gravy is eaten. When 300 g. of silver eels in portions weighing about 50 g. were stewed in 150 ml. of water for 20 min., the losses (%) were as follows: weight 25, protein 7.8, fat 12.4, Na 28.0, K 30.1, Ca 14.5, Mg 22.6, Fe trace, P 22.0, Cl 31.0. The amounts of these losses and the ratios of one to another are quite characteristic of a flesh food (McCance & Shipp, 1933). The composition of stewed eels may be computed from the above data by those who desire the information.

Table 6 gives the amounts of vitamin A, aneurin, riboflavin and nicotinic acid found in these eels.

Table 6. *Vitamins in uncooked eels*

The figures refer to muscle tissue only except in the case of elvers, which were analyzed whole.

	Elvers	Yellow eels. Average weights of groups analyzed				Silver eels. Average weights of groups analyzed			
		June catches		Autumn catches					
		103 g.	256 g.	188 g.	197 g.	197 g.	333 g.	678 g.	1400 g.
Vitamin A, i.u./100 g.	0	1500.00	300.00	2400.00	1500.00	900.00	3000.00	1800.00	1500.0
Aneurin, µg./g.	1.60	2.10	2.00	1.80	1.80	1.80	5.40	2.60	2.6
Riboflavin, µg./g.	2.93	3.82	5.16	2.60	2.50	3.00	4.20	3.20	2.9
Nicotinic acid, µg./g.	9.00	7.65	6.55	14.10	24.20	7.80	15.50	24.80	7.8

The food value of the eel

Elvers are considered a great delicacy in France and Spain. They have not got such a reputation over the whole of England, but they are caught in large numbers in the Severn and regarded as first-class fare all over Gloucestershire. Eels of the snig size, i.e. 20–25 cm. in length, are not eaten much if at all in this country, but, according to Vaillant (1903), they are much esteemed in France under the name of 'anguilles poulettes'. Of the larger animals, only the muscular tissues are eaten as a rule, although no doubt the livers would be very nutritious. The figures given by McCance & Widdowson (1940) refer to a mixture of stewed yellow and silver eels. The composition of the muscles of uncooked yellow and silver eels may be taken from Table 4, and the amounts of edible material and waste are given in the text. It will be appreciated that any food containing 27% of fat will have a high calorific value, and 100 g. of the flesh of a silver eel would provide the body with 300 cal., a figure which is probably higher than that provided by any other fish, and which compares favourably with the value even of the concentrated foods. The proteins must be of high biological value, but the mature animals cannot be regarded as supplying much Ca or Fe. The elvers are clearly very rich in Ca and would be as good a source of Fe as beef.

Muscular tissue only was analyzed, except in the case of the elvers, which were treated whole. It will be noted that the figures for aneurin and riboflavin were relatively constant. Those for nicotinic acid were less so and those for vitamin A were very variable, and the results bear no obvious relationship to the season of the year or to the amount of fat in the animals. The muscles are, however, a rich source of A, and very much richer than the herring (Bacharach, Cruickshank, Henry, Kon, Lovern, Moore & Morton, 1942).

SUMMARY

1. Data have been presented: (a) For the composition of elvers after some weeks in fresh water, and of yellow and silver eels of various sizes. (b) For the weight and composition of eel organs. (c) For the food value of eels and for their losses on cooking.

2. On a percentage basis, elvers contain less protein, fat, Na and K salts, and more water than older eels, and they must have a lower osmotic pressure. They are rich in iron and magnesium.

3. The next few years are characterized by an increase in the percentage of protein, Na and K and Ca salts. The percentages of water, iron and magnesium fall.

4. In the later years of growth and in the preparation for migration, fat is gradually deposited,

particularly in the muscles, with a corresponding fall in the percentage of protein, water, Na and K salts. The fall in Ca is greater than can be accounted for in this way.

5. The liver of a silver eel may contain over 100 mg. of iron/100 g. wet weight. There may be over 25 % of protein in the skin.

6. The above, and other chemical changes of growth have been correlated with events taking place in the body and with similar and dissimilar changes in the chemistry and growth of the higher vertebrates.

7. 100 g. of the flesh of a silver eel would provide

15 g. of 'first class' protein, and 300 cal. From the point of view of food, elvers must be regarded as a good source of Ca, P and Fe.

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Fat Formation in *Torulopsis lipofera*

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Several micro-organisms are known to be capable of storing considerable quantities of fat in their cells (Fink, Haehn & Hoerbuerger, 1937; Prescott & Dunn, 1940). The formation of fat in these organisms is either closely connected with growth, or very slow. These organisms therefore are not suitable for an investigation of the mechanism of fat synthesis. In the present paper the metabolism of *Torulopsis lipofera* (den Dooren de Jongh, 1926) was investigated. This organism lends itself particularly well for a study of fat synthesis because of its easy growth and rapid conversion of carbohydrate into fat.

MORPHOLOGY AND GROWTH OF *TORULOPSIS LIPOFERA*

T. lipofera was first described by den Dooren de Jongh (1926) as an asporogenous soil yeast, capable of storing large droplets of fat in its cells. Lodder

(1934) investigated the morphological properties and biochemical behaviour of this yeast somewhat more in detail. The strain of *T. lipofera* employed in the present study was obtained from the National Collection of Type Cultures. The yeast grows well on flour-wort-agar, or on simple inorganic medium (Stephenson, 1939) with 0.05 % marmite and carbohydrate, or on molasses containing NH_4 , K and Mg salts. Morphologically the cultures consist principally of oval cells containing several droplets of fat and some round cells with a very large fat droplet filling most of the cell volume (see Pl. 4). These two types of cells do not appear to represent different strains, because on single-cell isolation of the oval type of cells round cells also were found in subsequent subcultures.

Growth of T. lipofera. The growth conditions were studied by measuring turbidimetrically the growth rate of the yeast cultivated at room temperature