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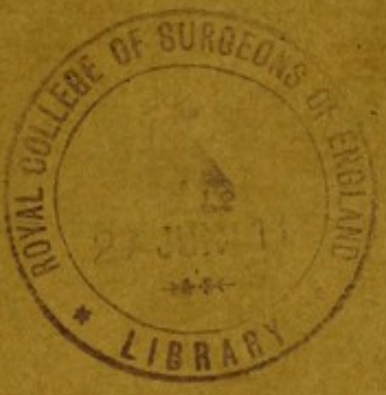
Reprinted from THE JOURNAL OF COMPARATIVE NEUROLOGY, VOL. 21, NO. 2, April, 1911.



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THE EFFECT OF UNDERFEEDING ON THE PERCENTAGE OF WATER, ON THE ETHER-ALCOHOL EXTRACT, AND ON MEDULLATION IN THE CENTRAL NERVOUS SYSTEM OF THE ALBINO RAT

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In 1904 Hatai ('04) studied the effects of underfeeding on the growth of the brain and on the percentage of water in the brain of the albino rat. Through underfeeding for 21 days with a diet free from proteids, he was able in one series of rats which were about 55 days old at the beginning of the experiment and weighed 67 gms., to reduce the weight of the brain by 12.8 per cent below that of the controls. Since during this period the brain weight of the controls had increased 7.6 per cent, it is plain that three-fifths of the difference found was due to an arrest of growth, and the remaining two-fifths to an actual loss.[1]

When this series of brains was examined for the percentage of water, the following was found:

Percentage of water in controls	79.11
Percentage of water in underfed	78.91
Difference	0.20

[1] Since Hatai wrote in 1904, we have obtained a much more complete and trustworthy series of standard weights and measures of the albino rat. I have substituted these for the standards originally used by Hatai and repeated the necessary calculations. No essential change has been introduced by this step, but the results have been slightly altered and probably made more accurate, and with Dr. Hatai's approval, I use the revised figures at this time.

Thus the underfed group was found to have a slightly smaller percentage of water, despite the fact that this group was composed of animals of the same age and from the same litters as those composing the control group.

We know from other studies that the percentage of water normally diminishes with advancing age (Donaldson, '10). It might have been expected nevertheless, as a result of underfeeding, that the change in water content—like the increase of the animal in size and weight—would have been arrested, but on the contrary we find that it has apparently been accelerated. The underfed group are in this character similar to somewhat older animals.

At the same time Dr. Hatai studied a second series of rats by a slightly different method. In order to get direct observations on the weight of the brain at the commencement of the experiment, the control group in this second case was killed at the time when underfeeding began for the remaining group. The final comparisons showed that through the underfeeding the weight of the brain had been reduced by 5.4 per cent below the initial brain weight, while the percentage of water was as follows:

Percentage of water for the control rats	79.01
Percentage of water for the underfed rats	78.71
Difference	0.30

It is seen at once that the difference in the percentage of water is greater in this second series than in the first. This greater difference is to be expected, however, owing to the fact that the control animals when killed were 21 days *younger* than those underfed; hence the difference found depends on the higher percentage of water in the younger controls as well as on the loss of water due to the underfeeding of the other group. These two series show that underfeeding, which causes loss of weight in the brain, reduces the percentage of water about 0.2 per cent.

In this same paper Hatai published determinations of the amount of ether-alcohol extract to be obtained from the control brains as compared with those underfed.

This table is so important in the present connection that I have copied it.

TABLE 1 (TABLE VI.; HATAI, '04.)

Showing amount of extractives in per cent

(In Series I, the controls were killed at the end of the experiment, and are the same age as the experimented. In Series II, the controls were killed at the beginning of the experiment, and are twenty-one days younger than the experimented.)

	SERIES I		SERIES II	
	OLDER	YOUNGER	OLDER	YOUNGER
	Extract in per cent	Extract in per cent	Extract in per cent	Extract in per cent
Control	47.1	45.8	48.06	45.8
Experimented	47.6	46.7	49.45	46.7
Difference	+0.5	+0.9	+1.39	+0.9
Average	+0.7		+1.15	

This table shows slightly more ether-alcohol extract from the underfed than from the control group, but it also shows that the older groups in each series—even when underfed—yield relatively more than the younger.

Since this ether-alcohol extract is mainly derived from the substances which compose the medullary sheaths, we may conclude that medullation has continued even in brains that have been losing in weight, although it must not be forgotten that some of the excess in the ether-alcohol extract is to be credited to the destructive changes caused by the underfeeding. Medullation then appears to be a second character which, like the percentage of water, is not notably modified by underfeeding.

Last spring I took up this matter again to see whether a new series would give similar results. In general, younger animals and less severe underfeeding were used. The animals were subjected to underfeeding when 30 days old, and having a body weight of 34 gms., that is about the middle of the most active growing period. The food contained some proteids, but was small in amount.

TABLE 2

Twenty-two litters were used. When a litter was thirty days old, underfeeding was begun with some of the animals and the rest reared as controls. At the age of fifty-one days all were killed.

The averages are given in Group 1 for the first seven litters; in Group 2, for the second seven litters; in Group 3 for the last eight litters.

	BODY WEIGHT		Br. Wt.	Cord Wt.	PERCENTAGE OF WATER IN	
	Initial	Final			Brain	Cord
Group 1						
Control.....	31.5	54.5	1.4977	.2709	79.420	74.187
Underfed.....	31.6	27.5	1.3757	.2343	79.338	74.399
Group 2						
Control.....	28.7	51.0	1.5029	.2785	79.327	74.267
Underfed.....	31.4	33.0	1.4007	.2534	79.314	74.249
Group 3						
Control.....	37.8	63.7	1.5633	.2986	79.430	73.561
Underfed.....	37.8	36.7	1.4286	.2602	79.195	73.525
Averages						
Control.....	33.1	57.0	1.5187	.2879	79.394	73.985
Underfed.....	34.0	33.5	1.4019	.2498	79.278	74.032
Difference....		−23.5	−.1168	−.0381	−0.116	+0.047
Percentage loss		41.2	7.7	13.2		

Table 2 gives the main results in the three groups into which the total number of 22 litters has been divided.

In the line where the percentages are given, it is seen that the underfed rats are only 41.2 per cent less in weight than the controls and have only 7.7 per cent less of brain weight. Indeed, unlike the results of Hatai, we have here a small growth in the weight of the brain in the underfed group rather than a loss, for according to my calculations the initial body weight of the underfed rats calls for a brain weight of 1.3526 and it will be seen that the brain weight observed—1.4019—is 3.6 per cent above this.

This failure to stop the growth of the brain and cord was doubtless due to several causes, not the least important of which

was the fact that these rats were younger than those used by Hatai, for it is apparently much more difficult without causing death to stop growth in the young than it is to reduce weight in the older individuals.

The variations in the percentage of water in the brain correspond with the degree of arrest. In every group the underfed have a smaller percentage of water in the brain than the controls and the average difference amounts to 0.11 per cent, while in the case of the spinal cord the controls differ materially from the underfed only in Group 1, but on the average such difference as is found is negligible. In Hatai's series there were no observations on the spinal cord and hence his paper gives no data for comparison on this point.

For the brain, however, Hatai found a loss of 0.2 per cent in the percentage of water, while in the present series, underfed for the same number of days, but less severely and at the same time somewhat younger, we record a loss of only .11 per cent. The difference in the conditions of the experiment furnishes, I think, ample explanation for the difference in the results.

While these determinations were being made on the percentage of water, one control and one underfed animal were selected from several of the litters and Dr. King prepared the brains from ten such pairs to show the degree of medullation as brought out by the Weigert method in frontal sections through the brain at the level of the optic chiasma.

By this means it was possible to study the degree of medullation in the brains of two groups—both 51 days old but one normal, while the other had been underfed for 21 days before death, this underfeeding having so retarded the growth of the brain as to make it on the average 7.7 per cent less in weight than that of the controls.

To test the preparations, the following simple method was used:

The slides were mixed and arbitrary numbers pasted over the descriptive label. The effort was then made, without knowing whether the section was from a control or an underfed rat, to arrange these slides in the order of decreasing medullation.

If underfeeding retarded medullation then in making the above arrangement we should get most of the controls in the upper half of the series and most of the underfed brains in the lower half.

The records of the arrangements were kept in the terms of the arbitrary numbers and only when all the tests had been completed was the true distribution of the sections determined by the identification of the slides from the two groups.

The test was made twice during a period of three days by two other members of the laboratory besides myself. The distribution of the slides as thus arranged gave no evidence that medullation had been arrested by underfeeding.

It will be seen that this result supplements that of the ether-alcohol extract as determined by Hatai, the relative amount of this extract being only slightly modified by underfeeding. The foregoing histological test is admittedly tentative and rough and requires to be repeated, but as it stands, it points to the continued formation of the medullary sheaths with advancing age even in animals which are underfed.

CONCLUSIONS

From the foregoing experiments we conclude:

1. That underfeeding causes a slight diminution of the percentage of water in the brain. This amounts to 0.2 per cent when the underfeeding is severe, as in Hatai's series, and 0.1 per cent when it is less severe, as in my own series.

2. Underfeeding when severe does not reduce but increases the percentage value of the ether-alcohol extract (Hatai). The percentage value of the ether-alcohol extract increases in the underfed during the 21 days of underfeeding by 1.15 per cent, while the effect of underfeeding in animals of like age at death is to increase the proportion of the extract only 0.7 per cent; thus an increase in sheathing substance occurs while underfeeding is in progress (Hatai, Series II), although some of the relative increase in the extract must probably be credited to the destructive changes in the neurone caused by the underfeeding.

3. The Weigert stain for the medullary sheaths does not reveal in the brain any notable difference in medullation between the underfed and the control rats. It is inferred that underfeeding does not arrest medullation.

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